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Oklahoma State University and University of Arkansas, Fayetteville Cooperative Report on Evaluation and Assessment Factors Affecting Water Quality of the Illinois River in Arkansas

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EVALUATION AND ASSESSMENT OF FACTORS AFFECTING WATER QUALITY OF THE ILLINOIS RIVER IN ARKANSAS AND OKLAHOMA

Submitted to:
Environmental Protection Agency, Region VI
Allied Bank Tower at Fountain Place
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PREAMBLE

For the purposes of the initial collection and analysis of data, responsibilities for the study were divided among three pairs of investigators from the two collaborating universities:

Chemical Water Quality	S.L. Burks & David Parker
Chlorophyll, Algae	David Francko & Richard Meyer
Fish, Macroinvertebrates	Jerry Wilhm and Art Brown

David Gade and Sarah Kimball were Research Associates assigned to Chemical Water Quality from Oklahoma State University.

Subsequently, consideration of the entire data set was considered by all investigators. Dr. Burkes and his Research Associates prepared the original text for the chemistry portion, Objectives IV and V, the Executive Summary, and a revision (January 1991) in response to a critique by the investigators from the University of Arkansas.

Final interpretation of the data was rather controversial among the authors, especially regarding the Chemical Water Quality portion. Following several discussions among the authors and others, further modifications were made by Dr. Brown and approved by Drs. Meyer and Parker. An attempt was made to keep these final revisions somewhat identifiable by listing them in the following outline. Essentially they emphasize water clarity and associated water quality parameters in the report which were the objectives stated in the proposal. Also, this final draft focuses on conditions in the river, as originally intended, above Lake Tenkiller. Lake Frances no longer exists since a flood washed out the dam in 1990. No changes were made in Objectives I, II or the Appendices.

<u>Revisions</u>

I. Title Page
   A. Insert reference to report.
   B. Change Department names for Drs. Brown and Meyer to "Department of Biological Sciences".
   C. Correct date.

II. Insert Preamble

III. Revise Table of Contents
   A. Establish parallelism by altering the sequence of topics in Objectives III, IV, and V as established in Objective II.
   B. Write Introductions for each of Objectives III, IV and V.

IV. Revise Executive Summary

V. Revise Introduction
   A. Shorten by:
      1. Revising statements under subheadings "Objective III, Objective IV, Objective V".
      2. Omitting material that could be a summary of results.
   B. Remove recommendations.

VI. Revise Objective III.
   A. Add Introduction.
   B. Change subtitle from "Phosphorus" to "Chemical Water Quality".
   C. Move entire sections "Turbidity, Nonfilterable Residue, and Chlorophyll" to immediately follow "Chemical Water Quality" subtitle.

VII. Revise Objective IV
   A. Add Introduction.
   B. Restructure as done for Objective III to maintain parallelism.
      1. Establish section entitled "Chemical Water Quality".
         a. Add subsection "Water Clarity".
         b. Place edited version of "Total Nonfilterable Residue" under "Water Clarity" section and drop the subtitle.
         c. Insert Note after "Phosphorus" subtitle.
         d. Revise last paragraph under "Phosphorus" subsection regarding Vollenweider's Index.
      2. Add Algae section.
      3. Add Fish section.
      4. Add Macroinvertebrates section.

VIII. Revise Objective V

   A. Add Introduction.
   B. Revise recommendation to a brief list.

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EXECUTIVE SUMMARY

This report was an attempt to acquire all of the archival water quality records available on the Illinois River up to the end of CY1986 and perform an objective scientific analysis to determine if a significant change in water quality had occurred in the Illinois River. The data were also to be evaluated to determine if the causal factors or sources of change could be identified. The ultimate goal of the project was to identify remedial actions which might restore the quality (especially clarity) of water in the Illinois River to acceptable levels mandated by both state and federal regulatory standards and also by esthetic and ecological criteria.

Analysis of the extensive data for parameters which indicate relative clarity of the water (turbidity, nonfilterable residue, suspended solids, chlorophyll and phytoplankton) do not indicate that any general trend of decreasing clearness of the water has occurred during the period of record. However, these data indicate that three specific reaches of the river have experienced significant decreases in water clarity: the area formerly in and below Lake Frances, the reach adjacent to Oklahoma Highway 10 upstream from the city of Tahlequah, and the reach immediately below the city of Tahlequah. The decreases in clarity in and below Lake Frances was probably due to the increased retention time which allowed algae to grow. The decrease in clarity along Highway 10 is coincident with an area of intense commercial and other canoeing activity, and associated developments and activities. The increased turbidity downstream from Tahlequah may be due to some impact of the sewage treatment plant for the city.

The impact of nutrients upon the primary producer community within lotic environments is difficult to quantify. Previous researchers had collected chlorophyll from the stream water column in an attempt to obtain some measure of the effect of enrichment upon stream flora. However, the bulk of the primary producer community in streams is attached to the bottom substrate and therefore is not measured by analyses of water column samples for chlorophyll a. The current data sets contain few direct measures of algal growth in the stream. Other problems with this simplistic type of assessment involve the fact that the river is biologically intense and complex. Algae are rapidly consumed by grazing invertebrates and fish which are in turn consumed by predators within and outside the stream.

Several parameters (turbidity and total nonfilterable residue) designed to measure suspended materials cannot be used as an index of the combined effects of biogenic and inorganic matter upon water clarity. These are not acceptable measures of the total effects of nutrient enrichment upon stream ecosystems because the nutrients are rapidly passed along the food chain. For plant nutrients to affect water clarity, they must result in increased standing crops of planktonic algae. Such is rarely the case in the stream.

The mean and median concentration of total phosphorus (P) exceeded the 0.100 mg/l level recommended by EPA as maximum level to prevent enrichment of streams or tributaries to standing bodies of water. Annual loading of phosphorus to the upper end of Lake Tenkiller is excessive. The consequences of a continued increase in loading rates to Lake Tenkiller would be deleterious to longterm water quality conditions in the reservoir. Most of the point source loading to Tenkiller originates at Tahlequah which is only six miles upstream.

The long term trends in nitrogen loading at USGS 07194800 showed a significant increase of 15,943 kg/yr over the period of record. The increase in loading rate was even greater at USGS 07195400, showing a significant trend of 71,933 kg/yr. The overall trend for most of the main stream sampling stations was an increase for the period of record. These long-term trends could be interpreted to indicate that while there was an increase in nitrogen discharge to the upper portions of the Illinois River, the biota along the length of the river assimilated most of the increased nitrogen. This should be reflected in greater production by primary producers along the length of the river. This in turn was probably passed along to grazing fish and invertebrates.

The data available did not indicate any significant spatial or temporal changes in suspended solids in the Illinois River. Generally non-filterable residues seem to be declining at most sampling stations along the river but they have significantly increased at SR 0.5 (formerly Lake Frances) and at SR 5.0 (above Tahlequah) where canoeing activity is greatest.

There were few significant changes in the structural composition of algae, benthic macroinvertebrate, or fish communities along the river. This may be due primarily to paucity of studies designed to detect such changes. Numerous studies have been performed on the biological community of this basin, but primarily for ecological research not pollution monitoring. The macroinvertebrate assemblage does seem to have shifted from a preponderance of collector-gathering types to filter feeders. This could be a response to increased seston quality, expected of a stream with higher algae production. The increase in filter feeders would remove food particles, including algae, and thereby keep algae standing crops and chlorophyll concentrations level. The community remains quite diverse and rich in species, a characteristic of communities at an intermediate level of disturbance.

INTRODUCTION

ABSTRACT

Considerable concern has been expressed recently concerning water quality in the Illinois River since portions of the river are used extensively for recreation and many individuals have perceived a decrease in water clarity. State agencies from Arkansas and Oklahoma have collected much data from the river, but it has usually been reported for those sections of the river within each state's political boundaries. We propose to collect and evaluate a water quality data and information base for the entire Illinois River basin and determine the completeness of the available data. We will analyze water quality changes, especially those parameters that effect water clarity, that have occurred in the Illinois River and identify potential control measures; however, the thoroughness of these tasks will be determined by the completeness of the data.

JUSTIFICATION

The aesthetic quality of the Illinois River has provided impetus for the development of a recreational-based tourism business of commercial canoe float trips and attracted many people to retire in the local communities surrounding the basin. The entire drainage basin in Arkansas as well as Oklahoma is used for recreational fishing and non-commercial canoeing. The Illinois River and Tenkiller Lake is also designated as a municipal and industrial water supply in the Oklahoma Water Quality Standards. The Illinois River from Lake Frances to the upper end of Tenkiller Ferry Lake has been designated as a scenic river by the Oklahoma Legislature and thus mandated to be protected from any degradation in water quality. In addition, the 1987 revisions to the State Water Criteria incorporated an "Antidegradation Policy" that protects any stream that is considered to be a valuable natural resource from any activity that causes degradation of that resource. During the past few years, water clarity has apparently declined in the Illinois River and Tenkiller Ferry Lake. The increasing numbers of user complaints and the reports of declining water clarity by field personnel of Oklahoma state water quality agencies have increased the awareness of a potential problem with the Illinois River and prompted state agencies to investigate the causal factors. Therefore, economic as well as ecological incentives exist to identify the factors related to a decline in Illinois River water quality and to develop preventive and/or remedial actions.

During 1985-86, personnel of the state water quality agencies of Arkansas and Oklahoma conducted an intensive collection of water quality parameters on the Illinois river from the headwater stations in Arkansas to the lower reaches in Oklahoma above Tenkiller Ferry Lake. This project was sponsored by EPA Region VI as well as cooperative contributions from the EPA Environmental

Research Laboratory in Corvalis, Oregon, and Duluth, Minnesota. The completeness of the available data sets and the analysis of water quality changes that have occurred in the Illinois River have not been determined.

OBJECTIVES

The objectives of this project will be to:

I) Develop a water quality data depository for the Illinois River emphasizing those parameters that influence water clarity,

II) Evaluate the completeness and quality of the available data,

III) Analyze changes that have occurred in the Illinois River,

IV) Identify cause or causes of change in water clarity, and

V) Identify possible control measures.

The thoroughness of objectives III through V will be determined by the completeness of the available data set.

WORKPLAN

OBJECTIVE I. DEVELOP WATER QUALITY DATA DEPOSITORY FOR THE ILLINOIS RIVER.

The state agencies of Oklahoma and Arkansas have recently compiled 2 years of stream monitoring data for the riverine portion of the Illinois. The agencies are logging this data into the EPA national water quality depository "STORET". All pertinent "STORET" data files for the Illinois River and Lake Frances will be accessed for this study. Water quality parameters that may influence water clarity will be emphasized.

Data not currently resident in "STORET" will be obtained from other state and federal agencies and entered into the duplicate OSU/UA data depositories. We will contact universities to locate published and unpublished data. We will contact private agencies, such as the Illinois Scenic Rivers Association, to determine if they will share data collected.

Prior to the 1985-87 surveys by Arkansas and Oklahoma agencies, limited water quality data were collected from the Illinois River basin and much of this was from localized areas. We must have a commitment of cooperation by state agencies to provide point source discharge data including flow volume, nutrient content, and suspended solids. We also will need access to technical documents and completion reports from other state and federal agencies involved with agriculture (e.g., Soil Conservation Service, U.S. Department of Agriculture, U.S. Geological Survey, Agricultural Research Service, State Conservation Commission, State Department of Agriculture, State Census Bureau). A detailed analysis of the 1964 and 1985 aerial photographs of the Illinois River basin is beyond the scope of this project. If the photographs have not been digitized and/or analyzed to provide specific data on land use, it will not be possible to use this information in this study.

OBJECTIVE II. EVALUATE THE COMPLETENESS AND QUALITY OF AVAILABLE DATA

The personnel working on the project have considerable experience in studying factors that influence water clarity and other factors associated with degradation of water quality. The available data that will be assembled in Objective I will be examined to determine the completeness of the data. The combined Arkansas and Oklahoma data sets will be distributed to the project personnel by subject. In this way a researcher will be responsible for information in his area of expertise for the entire river. This method of data analysis will provide a balanced approach, minimize any geographical bias, and maximize the use of knowledge of each participant.

The quality of the data will be evaluated on the following basis:

* laboratories with an accepted Quality Assurance/Quality Control plan (QA/QC) and analyzed with accepted EPA or ASTM protocols within appropriate periods from time of collection,

* laboratories with acceptable QA/QC plans using approved EPA methodology,

* laboratories without acceptable QA/QC plans using approved EPA methodology, and

* laboratories without acceptable QA/QC plans not using methods approved by EPA.

The quality of some data (e.g., historical data collected prior to QA/QC guidelines and research data) will be evaluated by the investigators to determine whether methods for collection and analysis were acceptable by the professionals in the field.

OBJECTIVE III. ANALYZE CHANGES IN WATER QUALITY IN THE ILLINOIS RIVER

All pertinent data obtained in objectives I and II will be used to try to determine changes in factors that may affect water clarity with time. Changes from headwaters downstream during restricted time periods will also be reviewed.

OBJECTIVE IV. IDENTIFY CAUSE OR CAUSES OF CHANGES IN WATER CLARITY

The purpose of this study was to attempt to identify the cause(s) of decreased water clarity in the Illinois River, with the supposition that such changes had occurred. It was hoped that existing data were sufficient to accomplish this. If they proved insufficient, subsequent appropriate data collections would be in order.

OBJECTIVE V. IDENTIFY POSSIBLE CONTROL MEASURES

Based on the success of Objectives III and IV, we were to identify potential procedures for preventing additional degradation and possibly improving water clarity in the Illinois River.

OBJECTIVE I

DEVELOP WATER QUALITY DATA DEPOSITORY FOR THE ILLINOIS RIVER

We located 168 articles related to the Illinois River. Most of the articles were state or federal agency reports. Many of the reports contained specific water quality data that were entered into personal computer data files for analysis in Objectives III and IV. A complete list of all reports and articles is presented in Appendix A. References to additional articles not in Appendix A but cited in the text are listed at the end of each section.

OBJECTIVE II

EVALUATE COMPLETENESS AND QUALITY OF AVAILABLE DATA

INTRODUCTION

Objective II was to evaluate the completeness and quality of the available data compiled on the Illinois River which was collected and compiled to fulfill Objective I. We assembled copies of most of the available data on the Illinois River and reviewed these articles. The completeness of the data sets was based upon both the period of record when the data was collected and upon the types of parameters collected. Since most investigators devised a new numbering system, we prepared a tabular summary of the locations of sampling stations on the Illinois River (Table 1) and also on the tributaries (Table 2). We cross-referenced each sampling station by river mile upstream from the confluence of the Illinois River with the Arkansas River. A map of the Illinois River basin was prepared to illustrate locations of sampling stations and associated river mile location (Figure 1).

CHEMICAL WATER QUALITY

Completeness

The primary objective of our overall evaluation was to determine the impact of anthropogenic activities upon water clarity. Therefore, the most useful parameters for this evaluation were measures of turbidity or suspended solids and algal density, i.e., chlorophyll *a* (Table 3). The early periods of chemical water quality data did not contain any parameters which would allow us to assess the clarity of water in the Illinois River. The USGS began analysis of turbidity at stations 07198000, 07196500, 07196000, and 07195500 in 1976 (Table 3). The Oklahoma State Department of Health (OSDH) Environmental Laboratory began analyzing turbidity at six sampling stations in 1980 in conjunction with efforts to establish the Illinois River as part of the National Scenic Rivers Act. The OSDH Environmental Lab began analyzing chlorophyll *a* as an index of the impacts of nutrient enrichment in the Illinois River in 1985.

In the past few years, the concentration of nutrients in the Illinois River was judged to be excessive when compared to other streams in low density population areas. The earliest data on nutrient concentrations was collected at USGS station 07196500 beginning in 1975 and continuing to present. A more extensive set of sampling stations, designated as Scenic River (SR), was established in 1980 and continued to the present by OSDH. The USGS station 07196000 on Flint Creek, a major tributary to the Illinois River, has nutrient data available for 1973 to 1986. Additional nutrient data has been collected for short intervals of time on the Baron Fork (USGS 07197000), and Ballard, Battle, and Tahlequah

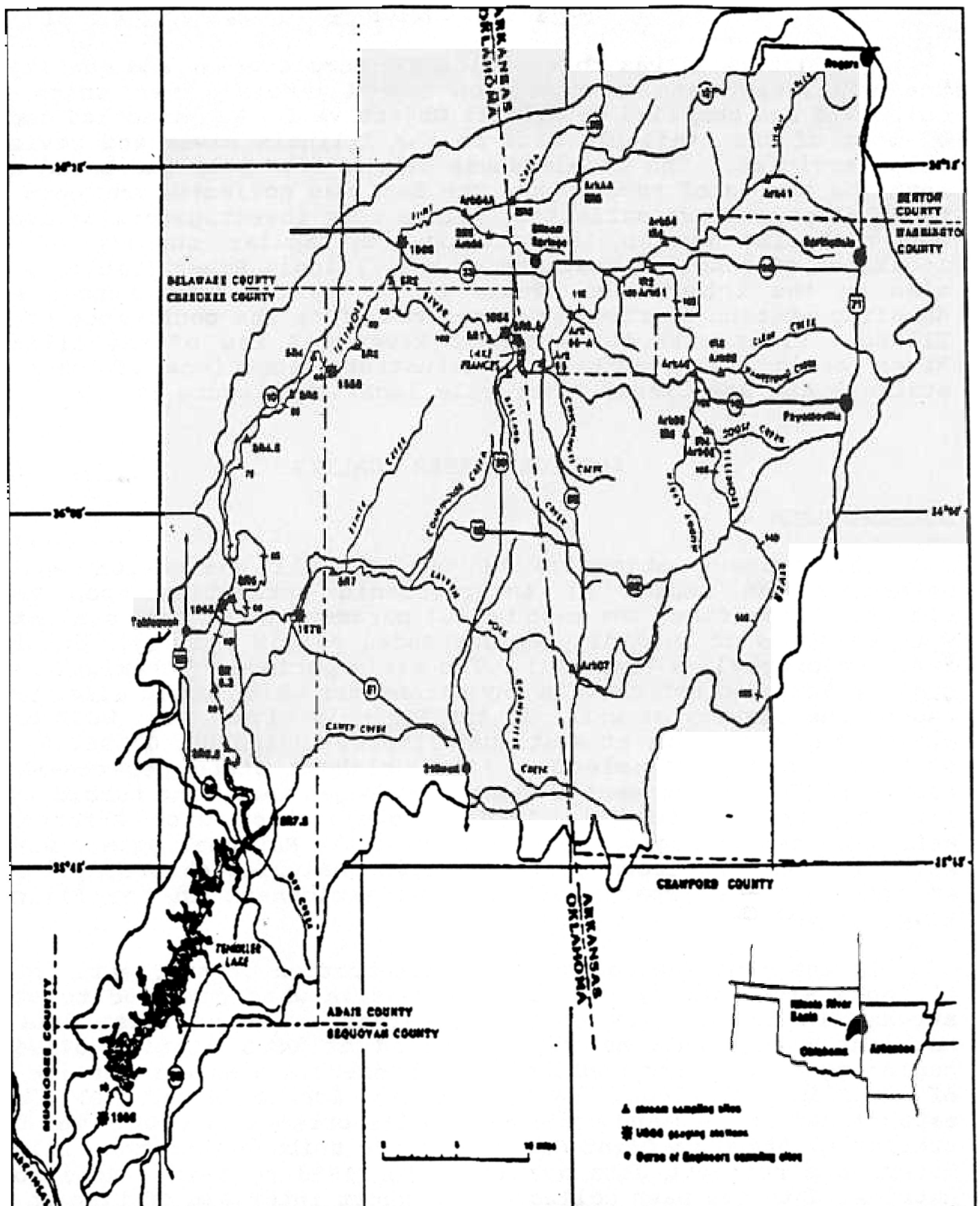

Figure 1. Map of Illinois River Drainage Basin showing river mile locations of sampling stations upstream from confluence with Arkansas River.

Table 1. Illinois River mainstem monitoring stations.

Station ID	Verbal Description	Legal Location	Longitude Latitude	River Mile
USGS 07194800	W of Savoy, Hwy 16 bridge	SEC36,T17N,R32W Wash. Co., AR	36 06 11.0 94 20 39.0	133.1
USGS 07195400	S of Siloam Springs, Hwy 16 bridge	SEC15,T17N,R33W Benton Co., AR	36 08 41.0 94 29 41.0	115.5
SR 0.5	Lake Frances on SW end of spillway	SEC17,T19N,R26E Adair Co., OK	36 08 00.0 94 33 05.0	108.0
USGS 07195500	Hwy 54 bridge N of Watts	SEC18,T19N,R26E Adair Co., OK	36 07 48.0 94 34 12.0	106.2
SR 1	Below USGS 07195500	SEC14,T19N,R25E Del. Co., OK	36 07 47.0 94 34 31.0	104.2
SR 2	100 yds above confl. with Flint Creek	SEC35,T20N,R24E Del. Co., OK	36 10 31.0 94 43 13.0	93.8
SR 3	Chewey bridge W of Chewey	SEC19,T19N,R24E Del. Co., OK	36 06 16.0 94 46 59.0	86.7
SR 4	Round Hollow State Park	SEC26,T19N,R23E Cher. Co., OK	36 05 30.0 94 49 55.0	82.3
SR 4.5	Comb's bridge W of Ellersville	SEC13,T18N,R22E Cher. Co., OK	36 02 10.0 94 54 30.0	74.8
SR 5	2 mi above USGS 07196500	SEC24,T17N,R22E Cher. Co., OK	35 56 25.0 94 54 58.0	57.8
USGS 07196500	At bridge on Hwy G2 2.2 mi NE of Tahl.	SEC26,T17N,R22E Cher. Co., OK	35 55 17.0 94 55 15.0	55.8
SR 6	Just below Tahl. STP	SEC11,T16N,R22E Cher. Co., OK	35 52 55.0 94 56 33.0	51.9
SR 6.3	S of Sequoyah Club above BF confl.	SEC24,T16N,R22E Cher. Co., OK	35 51 20.0 94 55 02.0	49.3
SR 6.5	At Horseshoe Bend PUA	SEC31,T16N,R23E Cher. Co., OK	35 49 00.0 94 54 00.0	46.1

Table 2. Illinois River tributaries and STPs				
Station ID	Verbal Description	Legal Location	Longitude Latitude	River Mile
USGS 07195860	Sager Creek 0.8 mi W of state line	SEC24,T20N,R25E Del. Co., OK	36 11 50.0 94 35 00.0	3.0
USGS 07195000	Osage Creek near Elm Springs	SEC21,R31W,T18N Benton Co., AR	36 13 19.0 94 17 18.0	10.0
USGS 07196000	Flint Creek at Hwy 33 bridge	SEC24,T20N,R24E Del. Co., OK	36 11 54.0 94 42 30.0	2.8
USGS 07197000	Baron Fork at Hwy 51 bridge at Eldon	SEC27,T17N,R23E Cher. Co., OK	35 55 16.0 94 50 18.0	8.8
Tahl. STP	Into Townbranch Creek	SEC03,T16N,R22E Cher. Co., OK	35 53 31.0 94 57 05.0	52.1

Table 3. Period of record, by water year, of selected water quality measures at monitoring stations.							
Station	Total P	Ortho-PO4	NO2 + NO3	NH4	Turb	Res. T-NFLT	Chl a
GS 1948	75-88	80-88	77*-88	77*-88	75-86*	75-88	85*
GS 1950	74*-87	81-87	77*-87	77*-87	81-87	74*-87	---
GS 1954	81*-87	79*,81 *-87	81*-87	79*,81 -87	---	81*-87	81*
SR 0.5	85*-86	85*-86	85*-86	85*-86	85*-86	85*-86	85*-86
GS 1955	70-72,73*, 75-86	85*-86	75,77*-86	85*-86	76-86	78-86	84*-86
SR 1	81-86	86*	81-86	85*-86	81-86	81-86	86*
SR 2	81-86	85*-86	81-86	85*-86	81-86	81-86	85*-86
GS 19586	74*-83, 85*-86	81-86	77*-83, 85*-86	77*-83,85*-86	73*-86	75-83,85*-86	---
GS 1960	76-86	85*-86	78-84,85*-86	85*-86	76-86	78-86	84*-86
SR 3	81-86	85*-86	81-86	85*-86	81-86	81-86	85*-86
SR 4	81-86	85*-86	81-86	85*-86	81-86	81-86	85*-86
SR 4.5	85*-86	85*-86	85*-86	85*-86	85*-86	85*-86	85*-86
SR 5	81-86	85*-86	81-86	85*-86	81-86	81-86	85*-86
GS 1965	76-86	85*-86	78-86	85*-86	76-86	78-86	84*-86
SR 6	81-86	86*	81-86	---	81-86	81-86	---
SR 6.3	85*-86	85*-86	86*	85*-86	86*	85*-86	85*-86
GS 1970	76-86	85*-86	78-84,85*-86	85*-86	76-86	78-86	84*-86
SR 6.5	85*-86*	85*-86*	85*-86*	85*	85*-86*	85*	85*
* indicates only partial data for that water year.							

creek. There were periodic studies of nutrient levels in Lake Frances in 1976, 1977, 1980, and 1981-82.

The availability of chemical water quality data prior to impounding Lake Tenkiller in 1952 is limited. We located two sources of preimpoundment chemical water quality data; the two USGS stations (07195500 and 07198000) and a fisheries study by Jenkins (1952), which cites the Oklahoma Planning and Resources Board, 1951 publication as a source for a summary table of chemical data. Since impoundment, only limited chemical water quality data has been collected from Lake Tenkiller. In 1974, Lake Tenkiller was sampled by the Environmental Protection Agency (EPA) as part of the National Eutrophication Survey (USEPA 1977a, 1977b), by Oklahoma State Department of Health personnel in 1975 (OSDH 1975), and by Tulsa District, U.S. Army Corps of Engineers (USACE 1979). In 1985-86, the Tulsa District Corps of Engineers initiated an intensive survey of chemical water quality parameters of Lake Tenkiller to coincide with the Oklahoma and Arkansas state agencies survey of the Illinois River (USACE 1988). The survey included monthly samples for nutrients, chlorophyll *a*, and conventional field parameters at 14 stations along the main axis of the lake.

There have been three separate reviews of the 1985-86 intensive survey of the Illinois River. Gakstatter (1986), Roberts/Schornick (1984), and Walker (1987) evaluated the chemical water quality data collected in 1985-86 and assessed the major contributors of nutrients and potential impact upon the river. In addition, Burks (1987) used the EPA QUAL2E river model to predict nutrient level input to Lake Tenkiller, with and without projected changes in municipal wastewater treatment plants.

We have obtained copies of 89 different reports and publications concerning some aspect of chemical water quality of the Illinois River and Tenkiller Lake, within the Oklahoma boundaries. The earliest period of record, beginning in October of 1947, of chemical water quality data was obtained from USGS station on Illinois River at Gore, Oklahoma (OPRB 1951). This sampling location (USGS station 07198000) has the most extensive period of record, periodiocally from 1947 to 1949, 1952, and then monthly data collections from 1954 to present. Another sampling location (USGS station 07195500) near Watts, Oklahoma has intermittent chemical water quality data starting in 1969 and regular monthly intervals since 1974. Several additional sampling locations were added in the early 1970's in conjunction with efforts to get the Illinois River designated as a National Scenic River. These sampling locations were sampled intermittently from 1974 to 1985. In 1985-86, an intensive sampling program was initiated by the Oklahoma and Arkansas state agencies to evaluate the potential effects of diverting part of the treated municipal wastewaters from Fayetteville, Arkansas, into a tributary of the Illinois River.

Quality of Data

Prior to development of a Quality Assurance/Quality Control plan and availability of "known" reference quality control samples by EPA in the mid 1970's, it was difficult to assess the quality of chemical water quality data. Most laboratories used the APHA/AWWA Standard Methods or ASTM approved methods for analyses, but had no formal program for analysis of "known" reference standards to check for accuracy of analyses. Most laboratories relied upon replication of analyses to check for precision or repeatability of a specific type of analytical procedure, but seldom had a "known" reference standard to check for accuracy.

Therefore, the quality of data generated by laboratories participating in a EPA Quality Assurance/Quality Control plan was considered as the best category. However, this does not invalidate data generated in the early 1970's and earlier. As indicated previously, most of the laboratories used standard methods and replication to control precision of their analyses. In recent years, all of the state and federal laboratories have adopted EPA or equivalent protocols. The EPA method number is entered into the EPA Storet system (Table 4). We accepted analyses from this period of time as precise and repeatable data, on a relative basis. If the absolute values reported from this period of time appeared to be outside the normal range of concentrations reported by other investigators, then the data was considered questionable and was either discarded or given less credence when determining trends.

Table 4. Agency method number identifier, descriptions, and standard units of water quality parameters.				
Water Quality Parameters	STORET Number	EPA Method Number	Description	Units
Turbidity JTU			Jackson Turbidity Units	JTU
Turbidity NTU	00076	180.1	Nephelometric Turbidity Units	NTU
Solids, Residue T-NFLT	00530	160.2	solids, residue at 105 degrees C, suspended	mg/l
Total Phosphorus	00665	365.2 (4.1)	phosphorus total, water	mg/l P
Ortho-phosphate	70507	365.2 (4.1.2)	phosphorus, ortho-phosphate, total	mg/l P
Ammonia	00610	350.3	nitrogen, ammonia total	mg/l N
Nitrite + Nitrate	00630	353.1	nitrogen, NO2+NO3 total	mg/l N
Chlorophyll *a*	32210			ug/l

Methods of Statistical Analyses

Water quality data retrieved from archival data bases were entered chronologically into personal computer spreadsheets for subsequent analysis with a software program designed to perform standard summary statistics, median temporal analyses, as well as trend analyses (WQSTAT II developed by Colorado State University (Phillips et al., 1989)). The data files were manually edited to discard some dates where one parameter was measured and another was not, to prevent WQSTAT from interpreting missing values as zero concentration. Multiple observations of a parameter in any one month of a particular year were arithmetically averaged to monthly means within the software package. Observations recorded as less than a particular concentration level in the data base (nondetects) were recorded as one-half of the detection limit.

Summary statistics were calculated for each parameter from the edited data sets for each sampling location. The summary statistics were calculated for seasonal, annual and/or total period of record, depending upon the comparisons desired. WQSTAT II expedited presentation of summary statistics by calculating the minimum, 0.25 quartile, 0.50 quartile(median), 0.75 quartile, and maximum distribution of a specific parameter and graphing the results in a box & whisker plot.

The distribution of the monitoring station data sets for each parameter was tested for normality based on skewness and kurtosis values. If either the skew or kurtosis value was significant the data distribution was probably not normal, thus supporting the use of nonparametric techniques for analysis (Fig 2).

WQSTAT II expedited analysis of temporal trends in water quality parameters by use of the Kendall-tau and the Seasonal Kendall tests. Both of these tests are nonparametric and compute results at the 95, 90, and 80 percent confidence levels, of the null hypothesis of no temporal trend in the selected data against a two-sided alternative of either increasing or decreasing trend. WQSTAT II also computed a trend line using the Seasonal Kendall Sen Slope Estimator. The Seasonal Kendall Sen slope estimate is a calculation where the slope between any two observations x_i and x_j, is calculated by $x_i - x_j$, where x_i and x_j are data values at times i and j respectively and $i > j$. The median of these individual slope estimates is calculated from the ranked individual slope estimates (Gilbert, 1987). Testing for trend using these methods can be viewed as a comparison of early observations in the series with later observations. The Kendall-tau test checks for a correlation between ranks of data and time. The seasonal Kendall test computes Kendall tau test statistics for each season (month or quarter) and combines them into an overall statistic (Fig. 2) (Loftis et al., 1989).

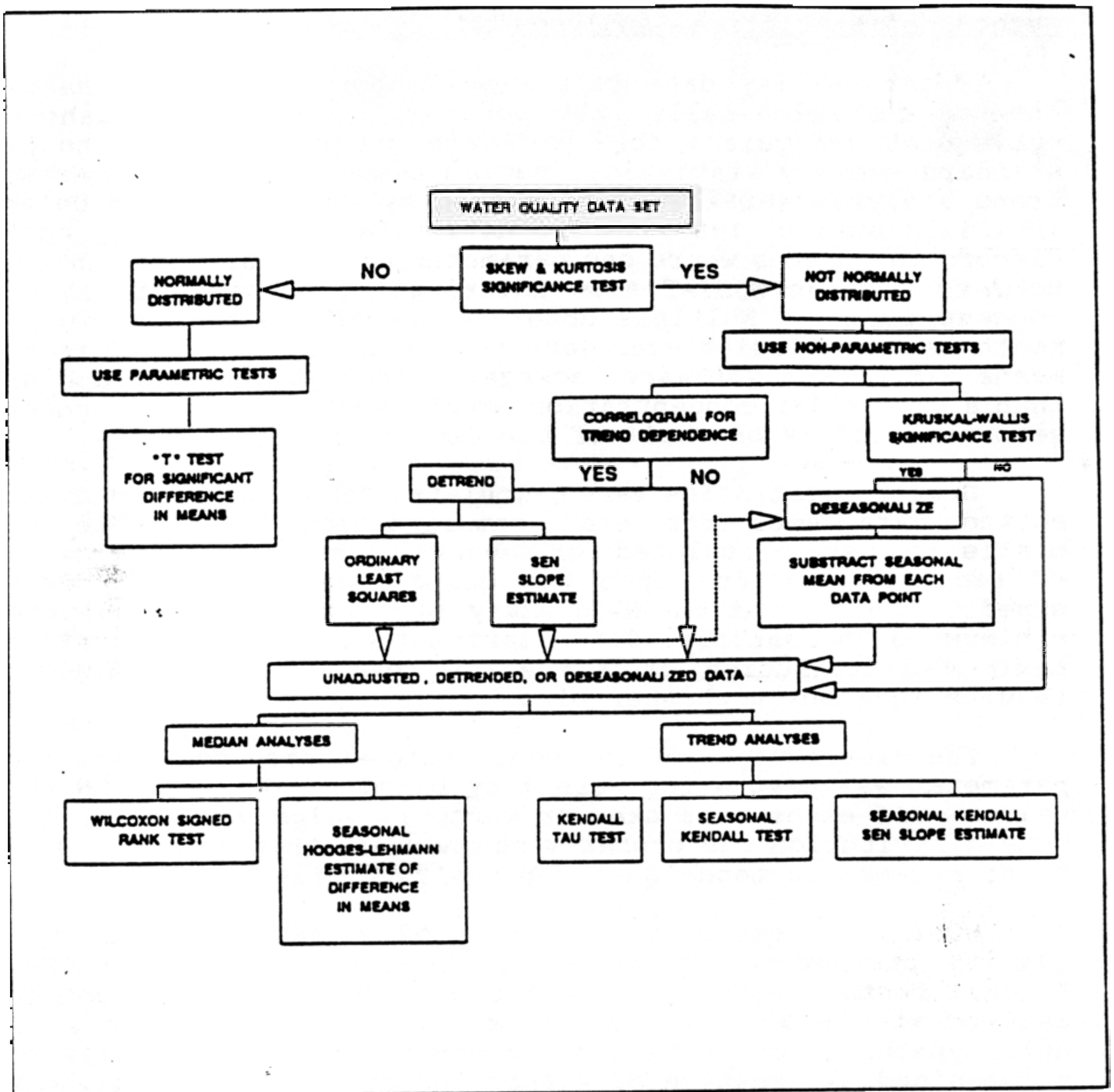

Figure 2. Flowchart illustrating the steps in preparing data for analysis and statistical tests used in WQSTAT-II.

A key assumption in the Kendall tau test described above is independence of observations. The Kruskal-Wallis test was used to check for significant seasonal variation (seasonality), a predictable change in water quality with time of year, at each of the monitoring station data sets. The Kruskal-Wallis test is a nonparametric test which checks for equal medians among three or more groups of data (Phillips et al., 1989). Results from this test were used to determine whether or not deseasonalization of the data would be required prior to performing the Kendall tau trend test. When seasonality occurred in the data set this assumption was violated. This was corrected by using a deseasonalization method which subtracts the seasonal (monthly) mean from the respective original observations thus smoothing the distribution. This method reduced the artificially increased variance of seasonality and increased resolution of the statistical analysis.

WQSTAT was also used to compare the median concentration of a specific water quality parameter from different sampling locations on the river, i.e., compare median phosphorus concentration at an upstream versus a downstream sampling station. The median analysis comparisons were also performed on median concentration of a parameter at a specific sampling location, but compared for different period of record, i.e., median of 1970-78 vs 1978-86, to dertermine if there had been a significant change in concentration over time. The actual tests for significance were a Wilcoxin signed rank test and/or the seasonal Hodges-Lehmann estimate of difference in means (Fig. 2).

ALGAE

Introduction

The species and cell density of algae found in lotic and lentic aquatic systems are important indicators of a system's trophic status. Long-term changes in the above parameters have been used to track the progress of eutrophication in inland waters. Eutrophied waters clearly have sufficient algal numbers to adversely affect water clarity.

We have examined 15 papers containing data on algal abundance, species composition, or chlorophyll concentration as an estimate of algal biomass and the relationships between biota and physicochemical parameters in the Illinois River drainage basin, including six studies on Lake Frances. These data were assessed to determine their appropriateness in determining distributional patterns and changes in these patterns over time. Specifically, we analyzed the utility of data in these papers in determining whether excessive algal growth could have been contributing to perceived historical declines in water clarity in the Illinois River. In our judgement, several sets of information would be required to make such a determination: 1) long-term data sets on algal numbers and/or chlorophyll concentrations for all major sampling stations using standard methods, adequate statistical replication, and sampling schedules that intensely cover both low and high flow periods; 2) information on the species composition of planktonic assemblages, with the same quality criteria above; and 3) long-term evidence that nutrient concentration in the river has been sufficiently high to support massive algal growth, and that historical increases in nutrient loading have been paralleled by increased algal growth.

The review of the papers and data sets have been divided into three categories: chlorophyll concentration as an indirect measure of algal biomass and two biological assemblages. The latter assemblages include the free-floating forms (phytoplankton) and attached taxa (periphyton). Certain reports contain one or more of the categories and are reported under each section below (see Appendix A for complete list of reports).

Chlorophyll

Of the 15 papers received containing some information as algae, only seven contained data on chlorophyll analyses, and one (OWRB,1986) dealt specifically with Tahlequah Creek.

The earliest chlorophyll data from within the Illinois River drainage are found in a report on Lake Frances (OSDH 1977) in which chlorophyll data for three lake stations are given on three sampling dates in 1974. These samples represented depth-integrated values but chlorophyll *a* determination reported (0.1-17.6 ug/l) were not replicated nor are details on methodologies or analytical error given. In 1981 and 1982, Soballe and Threlkeld (1985) conducted another study on Lake Frances using APHA (Strickland and Parsons) methods for chlorophyll *a* analysis, uncorrected for phaeophytin. This paper contains a full year of seasonal chlorophyll *a* data for standing crops to nutrient loading, implying that downstream loss of plankton may be great in this lake.

In 1981 and 1982, two studies examined chlorophyll *a* levels in the Illinois River itself (OKC-CHD 1982 and Terry et al. 1984). In the former paper, only two sampling sites were examined (USGS 1965 (RM 56) and USGS 1980 (RM 6) below Lake Tenkiller). Chlorophyll data presented are for two dates (30 Dec 81 and 1 Apr 82) and only for periphyton samples. In the later study, Arkansas stations corresponding to River Mile 138.1, 133.1, 124.6, and 115.5 were sampled (chlorophyll *a* was below 4.7 ug/l at all stations). Periphyton chlorophyll *a* at the same stations (4.6-50.9 mg/m2) was also given, but methods were not described.

During 16-29 August 1965, Gakstatter and Katko (1986) conducted a survey of 24 mainstream and tributary stations in Oklahoma and Arkansas plus Lake Frances and Lake Tenkiller. EPA methods were used and periphyton chlorophyll *a* was determined at some stations. No planktonic chlorophyll data were collected.

By far the most complete chlorophyll data set was produced by USACE (1987) and contains STORET chlorophyll data for the period 29 Mar 1984 through 30 Sep 1985 for 14 Illinois River stations from River Mile 132 (ARK 63) to about River Mile 56 (USGS 1965). Oklahoma data were not corrected for phaeophytin, whereas Arkansas data were. While the data set is quite complete in terms of covering most of the river on a bi-weekly basis for a fairly long period of time, the utility of the data set in determining changes in water clarity along the river or historically are unclear due to a high seasonal variation up to two orders of magnitude at the same sampling site through the period of study.

Phytoplankton

The eight data sets containing taxonomic lists and enumeration data for phytoplankton do not distinguish euplanktors from tychoplanktors. Thus, all of the records include periphyton dislodged by storm events, normal sloughing, and anthropogenic disturbances, etc. Those data reported to the generic level are of reduced value since many genera contain species which occur in both niches. Varying enumeration methodologies were employed. Only the August 1985 EPA intensive sampling study (Gakstatter and Katko 1986) included two sets of replicate samples.

The phytoplankton of Lake Frances has been reported in six studies covering a 10 year time span. A 1974 study as part of the National Eutrophication Survey reported the dominant genera in combined samples collected during the spring, summer and fall. These collections were enumerated to species via the Neubauer counting chamber method for inclusion in the EPA Working Paper 701 (Hern et al. 1978). A single summer 1976 collection from four depths, analyzed to species, was included in three Oklahoma State Department of Health reports (1976; 1978a, b). Analytical techniques were not included in these publications. In 1982 Threlkeld reported phytoplankton densities from five stations sampled from 21 Oct 1981 through 12 Oct 1982 using unknown methodology. Gakstatter and Katko (1986) collected three sets of samples during August 1985. These collections were analyzed to the species using the preferred Utermohl technique (copies of the original bench sheets are on file). The analytical methods for the several studies varied and no replicates were reported. The inconsistency in methodologies and resolution plus lack of repetitive long-term sampling reduces the usefulness of the above cited data.

Phytoplankton records from the Illinois River are presented in six reports. The earliest report by Rice (1975) includes eight stations from the upper Illinois River to Lake Frances. The algae are enumerated to genus using the Utermohl sedimentation technique. A single summer sample included four stations from above Lake Frances to above Lake Tenkiller by the Oklahoma State Department of Health (1976; 1978a, b). Details on sampling and analytical methods were not given although the 1978 summation and interpretation indicates that standard methods were used. Single phytoplankton samples were collected from two upper river sites in Arkansas in 1981 by the USGS (Terry et al. 1984). These data are reported to the genus using standard USGS enumeration procedures. Gakstatter and Katko (1986) collected three sets of phytoplankton samples at 24 points during August 1985 along a major portion of the river. These collections were analyzed with the Utermohl technique and the data summarized in the report (copies of the original bench sheets with species level enumeration are on file). Careful analysis of these data may results in a overview of the general distribution of phytoplankton.

The use of varying enumeration techniques and the lack of replication limits the use of the present information. Historical data on the phytoplankton of the Illinois River is sparse. Information on phytoplankton is limited to a 10 year span from 1976 through 1986. Within this period only two studies examined long reaches of the river while other collections were restricted in coverage. With detailed analysis, however, a general profile of the distribution of phytoplankton taxa and their abundance may be provided.

<u>Periphyton</u>

Three studies (Terry et al. 1985, Gakstatter and Katko 1986, Woomer 1986) examined the distribution of periphyton on natural and/or artificial substrates. Terry et al. collected algae from artificial substrates while Gakstatter and Katko scrapped periphyton from rocks. The Woomer study included both natural and artificial substrates. These studies are further contrasted in that Gakstatter and Kato collected periphyton from 24 river stations on three dates in August 1985, while Woomer concentrated on repetitive sampling from a single station and Terry et al. collected samples from two upper river sites. The first study (Terry et al. 1985) used standard USGS methodology, while the other two studies used the preferred Utermohl method for enumeration with data reported at the species level (copies of the original EPA laboratory bench sheets are on file). This high quality, but limited, data may provide an overview of periphyton distribution.

Conclusions

The chlorophyll data set on the Illinois River system is relatively sparse. Data on Lake Frances, while fairly complete and competently done, cover only a brief period during 1974 and then a more extensive period in 1981-82. Pigment data for the main river channel do not appear in the literature before 1981 and the only complete data set for large sections of the river is found in the STORET data for 1984-85 period and the Gakstatter and Katko's 1985 study during August. However, as noted earlier, the later study contained only periphyton data, while the former was restricted to planktonic pigments.

Thus, the pigment data sets may likely be too incomplete for historical trend analyses, although it may be possible to subject data from the mid 1980's to considerable scrutiny.

The phytoplankton data set includes surveys using different methodologies and taxonomic resolution. Lake Frances data from the EPA 701 Study (Hern et al. 1978), and EPA supplied laboratory bench sheets use different enumeration methods but report their results to species. The remaining data was analyzed to genus.

Most of the mainstream studies were restricted to the generic level with ubiquitous taxa noted (Terry et al. 1985, Rice 1974, OSDH 1978). Density data from these studies is of limited comparative value because of varying methodologies and the lack of replicates. With careful analysis of the combined data sets it may be possible to develop an overview of the qualitative and quantitative distributional patterns of the phytoplankton.

Three studies examined the periphyton using natural and/or artificial substrates. Varying methodologies were used in these studies. Studies by Terry et al. (1984) and Woomer (1986) were restricted to Arkansas stations. The former study was limited to genus, while the latter included an extensive analysis to species. USEPA (1985) laboratory bench sheets included enumeration to the species level from several stations during a three sampling dates in August, 1985. A summation of these data are presented the Gakstatter and Katko (1986) publication. The periphyton data are limited to a brief time span without prior historical data. With further analysis, these data may provide an adequate basis for a developing a generalized qualitative and quantitative assemblage structure along segments of the Illinois River.

The long time periods elapsing between data set collections, the large range in values reported even within discrete time intervals, and lack of details on procedures and statistical treatments in the majority of the papers examined make it doubtful that the existing literature could be used to examine historical changes in water clarity due to algal growth.

FISH

Although many fish studies have been conducted on the Illinois River since 1891, it is extremely difficult to compare the data and interpret changes because of the variation in sampling techniques, location of the stations sampled, unit of effort, time of year in which studies were conducted, and the methods of analyses and reporting data. Thus, the disappearance of fishes in the Illinois River over time may reflect variation in methods instead of environmental changes such as a decrease in water clarity.

We located 43 papers pertaining to the fish in the Illinois River. Many of them are of limited usefulness to the current project, i.e. analyzing factors that contributed to the decrease in water clarity of the Illinois River. Fish papers on the Illinois River that will be used to assemble a species composition list for the basin but which are of limited use to the goals of the project are the following (file number in parentheses):

ADPCE & USEPA (20) - Fish collected from Flint Creek on one date in 1983.

Andreasen (65) - Neither chemical nor metal residues in bottom feeders, predators, and shad exceeded the geometric means of all samples.

Armstrong et al. (111) - Feeding of channel catfish in the Illinois River.

Black (113) - Distribution of fishes in Arkansas.

Brown et al. (112) - Downstream drift of various fish species in the Illinois River.

Buchanan (126) - Key to fishes of Arkansas.

Burr (128) - Two new fish species collected in the Illinois River.

Cox (8) - Collected 45 species of fish in the Flint River.

Deppert (6) - Predation of trout by white bass existed at only one of three stations in the lower Illinois River; dissolved oxygen concentration limited trout in fall.

Felley (131) - Multivariate assessment of preferences of cyprinid fishes.

Finnell (151) - Trout did not reproduce in the lower Illinois River; a fishery would require continual replacement.

Geihsler et al. (78) - Reported 62 species in the Arkansas part of the Illinois River.

Gelwick (132) - Fish in Battle Branch; species richness in pools increased downstream and assemblages in pools were more stable than in riffles.

Hall (18) - Postimpoundment survey of fish in Tenkiller Reservoir.

Hubbs (107, 108) - Notes in 1929 of Oklahoma fishes.

Jenkins et al. (135) - Fisheries investigations of Tenkiller Reservoir.

Leonard (25) - Growth of basses in the Illinois River; growth of smallmouth is faster in the river than in more northern states but slower than in the TVA reservoirs.

Meek (140) - A 1891 catalog of the fishes in Arkansas.

Moore (105) - Field notes of fish surveys; a few were conducted in the Illinois River.

OCC (32) - Study of the water quality and fish in Battle Creek.

ODWC (34) - Estimated that an input from an egg farm killed $237.87 worth of fish.

ODWC (48) - Collected one tagged striped bass in the lower Illinois River below Tenkiller Dam; bass was released in the Arkansas River below Keystone Dam.

Olmsted et al. (130) - Repopulation after fish kill in Mud Creek; most species repopulated the kill zone within 1 yr.

OSDH (57) - Raw data of fish collected in 1974 and 1976 surveys.

OSDH (45) - PCB, chlordane, DDT, aldrin, toxaphene, and heptachlor of fish in Tenkiller Reservoir were well within FDA limits.

OSDH (11) - Preliminary study to OSDH (1986, File 12).

OWRB (11) - Preliminary study to OWRB File 12.

Paden (64) - Predicted 49 species that could be expected in Ten killer Reservior.

Pigg (91) - Field notes and summary tables that also are in OSDH (File 69).

Power et al. (143) - Grazer control of algae in the Baron Fork; diatom tufts were stripped quickly by minnows and replaced by cyanobacter.

Riggs (22) - Collected river darters in the Illinois River.

Robison et al. (127) - Fishes of Arkansas.

Summers (23) - Fish in Illinois River below Tenkiller Reservoir; low dissolved oxygen measurements suggest that trout would not thrive in the region in summer.

Threlkeld (62) - Report of existing data on Illinois River, no new data.

Todd et al. (149) - Food habits of nongame insectivorous fish in Flint Creek; complex interaction of habitat and prey size selectivity influence resource partitioning among fishes.

USDOI (59) - Report of existing data on Illinois River; no new data.

Whitworth (21) - Collected 28 species of fish from tributaries to Tahlequah Creek.

Cloutman and Olmsted (1976) provided an excellent summary of the changes in the abundance of fishes in the Illinois River in Washington County AR related to the activities of humans. They reported that the Paleo-Indians immigrated into northwestern Arkansas as early as 9500 B.C. It is doubtful that these early residents had any significant impact on fishes since the small, nomadic bands relied mainly on mammals for sustenance. A growth in population and an increase in exploitation of natural resources occurred from 7000 B.C. to 1000 A.D. when the Indians of the Archaic stage inhabited northwestern Arkansas. Animal remains suggest that Indians from 500-1000 A.D. were hunting and collecting nearly all mammals, larger birds, fish, mussels, and turtles that are present in this area today. Nearly 40 species of fish were being used for food at that time; however, these Indians probably had a small influence on local fish populations.

The territory was largely abandoned by Indians in the first part of the nineteenth century and opened for settlement by the white man. Population growth was slow but steady and it is unlikely that humans had a significant impact on the streams even though forest clearing and farming were practiced. Early references did not mention any kind of pollution. Development of tractors and other farm implements created a boom in agriculture in 1920 and by 1940 farmland accounted for over 50% of land use in the county. It was noted that the fishing in 1940 was less satisfactory than 15 or 20 years previous. After 1940, urbanization increased and the number of farms and farmland decreased. In spite of the decrease in farmland, organic pollution of streams started to increase due to larger numbers of livestock and poultry. Presently, most of the pollution in Washington County is derived from drainage of wastes from cattle and poultry into the streams. Although most streams in Washington County still are relatively clear and have gravel substrates, water quality has generally been reduced and local silting and increased turbidity has occurred. The absence of several species of fishes suggest that there has been an increase in turbidity since 1940.

Cloutman and Olmstead stated that little industrial pollution existed in Washington County in 1970. They were unaware of any recurring kills due to chronic pollution. Although no fishes have been eliminated from the county because of humans, occasional spills of toxic substances into local streams have occurred. Little stream channelization or dredging has been done in Washington County. Impoundment of several streams has had the most significant impact on many fishes of the county. Impoundment of stream has eliminated many kilometers of prime pool and riffle habitats and has had the most significant impact of man on fishes. At least six species of fishes have been severely depleted or possibly eliminated from Washington County due to habitat destruction resulting from impoundments. Humans have also introduced exotic fish species such as the carp, trout, threadfin shad, northern pike, white bass, striped bass, and goldfish.

In addition to the 31 papers listed above, we analyzed 12 papers of fish studies on the Illinois River from the headwaters to Tenkiller Reservoir more thoroughly. Considerable variation exists among studies in sampling methods, stations sampled, and the duration of the study. Sampling methods include seines of many types, gill nets, electroshocking, rotenone, and angling. Most studies were limited to a particular section of the Illinois River. Fish have been sampled in over 48 different stations in the Illinois River from the headwaters to Tenkiller Ferry Reservoir and its tributaries. Nine of the 12 studies were conducted in the 1970's or 1980's. Only three papers were analyzed for the period from 1946-52. Most studies were conducted exclusively in summer.

None provided data that would be useful in demonstrating factors that contribute to the decrease in water clarity. The papers are presented in chronological order.

Ninety-two species of fish were collected at 10 stations in the Illinois River from Lake Francis to the mouth in 1946 (Moore and Paden 1950). George Moore, a prominent ichthyologist at Oklahoma State University from 1923 to 1968, made many collections from the Illinois River dating back to 1920's. Moore stated that the river is one of the richest in the United States in regard to the number of fish species. He recognized the excellent location between the Gulf and the Great Lakes. The supply of Ozark spring water enabled establishment of fish from the Ozark Uplands and the plains fauna reached the Illinois River from the Arkansas River.

Several studies were conducted on the Illinois River in the 1950's. Jenkins et al. (1952) collected 75 species of fish from June to August 1952. They sampled 22 stations from the Oklahoma-Arkansas border to Gore OK. They stated that the Illinois River has a diverse and abundant fish population. Smallmouth bass were particularly abundant. The predicted changes in fish distribution that would result from impoundment; i.e. Tenkiller Dam. Hall also reported in 1952 that the fish assemblage in the Illinois River was abundant in number and variety. All of the native game and pan fishes, except the white bass and sauger, were found above the dam in sufficient numbers to insure good populations in Tenkiller Reservoir. Freshwater drum, buffaloes, redhorses, the river carpsucker, and flathead catfish were already established in the lake in 1952.

Several studies have involved collecting fishes in the headwaters of the Illinois River. Cloutman and Olmsted (1970) reported 66 species of fish in the Illinois River drainage in Washington County AR. They made 122 collections at 78 sites from 1970 to 1974. They found many fish that are widely distributed in eastern United States as well as several species that have an Ozarkian distribution. Several prairie and lowland forms that occur downstream in the Illinois River were lacking in Washington County. Kiddle et al. (1974) collected 48 species of fish from eight stations along the Illinois River in Washington and Benton counties Arkansas in June 1974. They reported five species not previously reported. Ebert et al. (1987) collected 30 species representing ten families of fish in five headwater riffles of the Illinois River system in Washington County during low flow. Darters, sculpins, madtoms, and stonerollers comprised from 68 to 98% of the total species collected in the riffles. Although fish numbers decreased from the heads of riffles to the tails, the number of species increased.

The Oklahoma State Department of Health collected 67 species at 20 station in an extensive study in 1976-77 (OSDH 1978). Although 29 species were thought to have disappeared from the river, this may have been due to the restriction of movement upstream by Tenkiller Dam. The number of species taken at one station ranged from eight to 48 demonstrating the difficulty in comparing Illinois River fish data collected at different stations. Fish species diversity ranged from 0.47 at a private camp which had a heavy recreational use in summer to 3.87 at a station below Lake Francis. The authors felt that the high diversity resulted because Francis Dam restricted upstream movements and fish accumulated in this area and some fish could have escaped from Lake Frances after it was stocked. Two other reports are included much of the same data as File 58. In an earlier report (OSDH 1976), the Oklahoma Health Department reported that 108 species of fish had been collected in the Illinois River to 1976. This number included five species stocked in Tenkiller Reservoir that had not been collected above the reservoir; threadfin shad, blue catfish, walleye, muskellunge, and rainbow trout. In a 305(b) Technical Report for Oklahoma (OSDH 1980), the Oklahoma Health Department summarized trends in the river. Based on the number of species, species diversity, and number of dominant species of fish, they felt that conditions were improving over time in the Illinois River from Watts to Tahlequah, Oklahoma, while the trend over area was unknown.

The Oklahoma Department of Wildlife Conservation collected 69 species of fish in surveys conducted in 1974, 1981, and 1982 at 10 stations (Smith 1985). They used boat electrofishing and seining and riffle disturbance sampling. They collected more species from the lower one-third of the river than in other sections, while the fewest numbers of species were taken in the upper section. More pollution tolerant species inhabited the turbid section of the river. The author felt that sampling tributaries, springs, oxbows, and additional mainstream sites would have increased the number of species collected to the number expected. About one-third of the species were more common than that reported by Pigg in 1978 and only five were less abundant. Smith found that the three black bass species and the largemouth and spotted bass increased since the late 1940's and 1950's; however, the abundance of the smallmouth bass has decreased.

The Oklahoma State Department of Health (1985) provided temporal variation of fish data collected in the Illinois River near Tahlequah (Station 1965) from 1976 to 1983 (Table 5). Number of species and species diversity ranged from six to 23 and 0.76 to 4.10, respectively. A total of 55 species were collected from 1976-83 near Tahlequah, while species diversity averaged 2.73. Intolerant and sport fisheries ranged from three to 12 and zero to six respectively. During the entire period, 179 rare fish were collected. The mean percent composition of the intolerants, sport, and rare species were 54, 2, and 1%, respectively. In a study in a third order segment in Tahlequah Creek in 1986 (OWRB 1986), the number of species at four collecting stations ranged from 16 to 22, while species diversity ranged from 1.57 to 2.28.

Table 5. Temporal variation of fish data collected in the Illinois River at Tahlequah (Station 1965).

	Species Collected	Species Diversity	Intolerant Species	Sport Species	Rare Fish
16 Jun 76	16	0.76	7	0	5
19 Jun 78	15	1.08	8	0	10
17 Jul 78	19	1.68	7	5	1
11 Jun 79	19	1.54	7	3	5
09 Jul 82	18	1.54	6	4	5
22 Oct 79	12	1.91	7	2	0
07 Apr 80	14	2.91	4	0	21
24 Jun 80	18	1.93	8	3	1
23 Jul 80	19	4.10	12	6	17
12 Oct 80	15	2.26	8	4	1
01 Jul 81	16	1.22	8	2	1
04 Aug 81	20	2.11	11	4	10
24 Oct 81	17	2.73	8	2	8
06 Jul 82	20	2.20	7	4	9
26 Jul 82	20	1.86	9	5	0
23 Oct 82	6	1.96	3	2	0
15 Jun 83	17	1.83	9	1	0
21 Jul 83	23	2.04	12	6	0
29 Oct 83	15	2.88	9	2	78
22 Jun 84	25	1.57	11	4	7
31 Jul 84	26	1.87	14	5	22
13 Oct 84	18	2.80	13	4	19
19 Jun 85	26	2.14	14	6	11
07 Aug 85	16	2.57	7	4	2
05 Oct 85	16	2.85	10	4	0
15 Jun 86	19	2.84	9	5	3
Cumulative	55	2.73	23	13	236

The Oklahoma State Department of Health (1985) also provided data on longitudinal variation of fish data in the Illinois River from 13-16 Jun 76 (Table 6). Number of species ranged collected from 14 to 41 and species diversity from 0.46 to 3.79. No particular trend existed in numbers of species collected or in species diversity; however, these variables were considerably higher at Station 1955-Watts. Numbers of intolerant species increased from eight at Station 1950-Chewey to 14 at Station 1955-Watts and then decreased to 10 at Station 1958-Flint River. The number of species of sport fishes was considerable higher at station 1955-Watts than at other stations.

In all of the various studies in the Illinois River drainage, 117 species have been collected at one time or another (Smith 1985). Smith stated that of the 40 species no longer expected from the mainstream of the Illinois River, Flint Creek, Barren Fork Creek, and other tributaries between Francis Dam and Tenkiller Ferry Reservoir, 15 are presumed to have disappeared from the drainage, six are expected only from the Arkansas section, five may inhabit Tenkiller Reservoir and would not normally move into the river, and 14 may still inhabit the lower Illinois River below Tenkiller Dam.

Smith felt that there have been few fish fauna introduced into the Illinois River since 1952. He noted that the changes in species composition and distribution have been gradual. Tenkiller Dam has prevented the upstream movement of several species that periodically would enter the Illinois River to spawn and/or to feed. The construction of the dam was more influential in reducing species composition than habitat changes, increased recreational use, and pollution problems. He felt that species composition, abundance, and distribution of fish would be better in the upper station if Lake Francis did not contribute turbid water.

Although the data provides considerable information on the species abundance of fish in the Illinois River, it is difficult to relate changes in species composition to the decrease in water clarity in the river. It is unfortunate that uniform methods to collect fish data and water quality parameters were not used over time which would enabled analyzing meaningful trends.

Table 6. Longitudinal variation of fish data collected in the Illinois River from 13-16 Jun 76.

Station	Species Collected	Species Diversity	Intolerant Species	Sport Species	Rare Fish
1950 - Chewey	14	1.29	8	5	8
1953 - Low Water Dam	22	1.57	13	5	24
1955 - Watts	41	3.79	14	14	12
1958 - Flint Creek	16	2.00	10	3	531
1961 - Round Hollow	19	1.99	11	6	18
1962 - Scraper	19	1.42	10	5	8
1963 - Hanging Rock	18	1.24	11	2	24
1964 - Pea Vine	18	2.04	10	5	28
Eagle Bluff	17	0.46	11	5	4
No Head Hollow	15	1.72	10	3	1
Sparrow Hawk	20	1.69	8	3	5
1965 - Tahlequah	16	0.76	7	0	5

BENTHIC MACROINVERTEBRATES

Environmental pollutants induce changes in the structure and function of biological systems. As a result, many biologists have attempted to judge the degree and severity of pollution by analyzing changes in biological systems. Although biological changes occur at all levels of organization from molecules to the community, the earliest use of biological indicators involved using the occurrence of particular species. Plants and animals in a stream have been classified according to their tolerance of organic pollution in such a way that a graded list of them may serve as an index to the degree of contamination.

Many investigators have found problems using the pollution tolerance of organisms and have resorted to other methods of analyses. The use of diversity indices have been commonly used during the past two decades. Diversity indices provide a numerical index that has been related to the degree of pollution. It has been recognized that an adequate sample size of organisms must be collected and that diversity indices should be used in association with other data.

Benthic macroinvertebrates are particularly suitable as ecological indicators because their habitat preference and relatively low utility cause them to be affected directly by substances that enter the environment. Macroinvertebrates are easier to identify, analyze, and preserve than microscopic organisms.

We located 28 articles that pertained to the benthic macroinvertebrates in the Illinois River basin. Most of them are of limited usefulness to the current project, i.e. analyzing factors that contribute to the decrease in water clarity of the Illinois River. Benthic macroinvertebrate papers on the Illinois River that will be used to assemble a species composition list for the basin but which are of limited use to the goals of this project are the following (file number in parentheses):

Armstrong (111) - Benthics in drift and fish stomachs
Brown et al. (116) - Leaf detritus use in a riffle
Brown et al. (119) - Processing of detritus in an Ozark stream
Brussock (117) - Leaf decomposition in an Ozark cave and spring
Brussock (118) - Benthics in an Ozark cave and spring
Brussock (125) - Benthic macroinvertebrates in relation to stream geomorphology
Ebert et al. (120) - Benthics in stomach of fish
Gibson (133) - Benthics of an Ozark spring in Arkansas
Gordon et al. (121) - Mollusks in the Arkansas reaches
Gordon et al. (122) - Mollusks in the Arkansas reaches
Gordon (123) - Fingernail clam in southwestern Ozarks
Isley (136) - Mussel fauna of eastern Oklahoma
Petty (124) - Leaf processing in a slough
Power et al. (143) - Grazers control of algae in the Baron Fork
Sublett (147) - Benthics in rapids of one tributary
Sublett (148) - Publication of file 147
Threlkeld (62) - Lake Francis study
Unzinker (150) - Caddis flies in Arkansas reaches
Walker (101) - Proposal

Eight benthic macroinvertebrate studies were analyzed more thoroughly. Unfortunately, none of them have been over long periods of time which would enable analysis of long-term changes of benthic macroinvertebrates and perhaps stream conditions. In addition, most of them are not quantitative and none of them used a statistical design. Comparisons are further complicated because of variation in stations sampled and in sampling gear. Sampling gear involved Hester-Dendy samplers, ponar dredges, basket samplers, and aquatic dip nets. Only three of the eight studies identified point and/or nonpoint sources of pollution and only one attempted to study changes in river conditions during the period of study. None of the studies compared results with previous studies and analysis of the benthic community does not enable demonstrating factors that might be contributing to the decreased in water clarity.

Several studies involved tributaries to the Illinois River. Two stations were sampled on Spring Creek, one immediately upstream of Springdale Sewage Treatment Plant and one 1 mile below the sewage outfall (ADPCE and USEPA 1984). The authors measured a decrease in diversity of benthic macroinvertebrates from 3.61 above the outfall to 1.14 below the outfall. Values exceeding 3.0 usually suggest good water quality and values less than 1.0 indicate stress. Values from 1.0 to 3.0 suggest intermediate conditions. McCraw (1977) conducted a survey of the benthic macroinvertebates in Clear Creek which discharges into the Illinois River near Savoy AR. Although he reported low species diversity values and possible adverse conditions in the headwaters of Clear Creek, species diversity increased abruptly downstream prior to the entry of Clear Creek into the Illinois River. He felt the most influential factors reducing diversity in the upper reaches were allochthonous input, disturbances of the stream bed, and the small particle size of the sediments. Studies on Tahlequah Creek were made in 1985 and 1986 (OWRB 1986). The authors concluded that both numbers and diversity of benthos were reduced considerably in the segment of the creek that is impacted by the seepage effluent. However, a study in the Illinois River at Tahlequah reported that conditions in the river must be good based on indicator benthos and diversity. The Oklahoma City-County Health Department (1982) collected diverse assemblage of benthic macroinvertebrates in the Illinois River at Tahlequah.

One of the most extensive studies involving benthic macroinvertebrates was conducted in Lake Frances and at three stations on the Illinois River in Summer, 1976 (OSDH 1976, OSDH 1978, OSDH 1978a). The stations sampled were 282 (Lake Frances), 283 (above entrance of Flint Creek), 274 (Comb's Bridge), and 256 (below Tahlequah). At the four stations, the number of species of benthic macroinvertebrates were 8, 23, 36, and 39, respectively, while diversity average 0.80, 3.58, 3.84, and 3.69. The authors concluded that the number of species and the diversity values suggest poor water quality in Lake Frances and healthy conditions at the three riverine stations. Plecoptera or stoneflies, that are usually absent when pollution is severe, decreased downstream below Station 283. Hydropsyche or caddis flies were higher at Station 274 and absent at Station 256. Diptera increased downstream which could indicate increased levels of organic enrichment; however, some of the dipterans collected are classed as sensitive to enrichment. Although this study also measured water quality at the collecting stations, it is of little value in demonstrating long-term changes in river conditions or in illustrating factors that contribute to the decreased in water clarity.

The Oklahoma State Department of Health published a 305(b) Technical Report for water years 1978-78 in which the trends in benthics macroinvertebrates were described (OSDH 1980). They reported that based on the numbers of genera, generic diversity, and numbers of dominant genera of benthic macroinvertebrates, spatial trends are generally improving in the Illinois River from Watts to Tahlequah and degrading from Tahlequah to Gore. The temporal trends are unknown in the upstream reaches and results are inconsistent in the lower reaches. For example, in the reach from Tahlequah to Gore, numbers of genera suggests that temporal trends are degrading, numbers of dominant genera suggest stability, and the trend is unknown based on genera diversity.

OBJECTIVE III

ANALYZE CHANGES IN WATER QUALITY OF THE ILLINOIS RIVER

INTRODUCTION

Extensive analyses of the water quality data available for the Illinois River Basin were performed. Despite this, no clear picture emerged depicting a general decline of water quality in the basin through time or spatially. However, considerable variability in water quality among sites was detected in the basin. Water clarity was found to be lowest at three sites : 1) in and below Lake Frances (SR 0.5 -> SR 1.0), 2) in the reach along Oklahoma Highway 10 where canoeing is very intense (SR 4 -> SR 5), and 3) below the Tahlequah, Oklahoma treated sewage discharge (SR 6.3).

Plant nutrients are generally high relative to other Ozark streams and increasing at a few sampling stations, but this has not resulted in higher algal standing crops (or less clarity) in the river. Excess nutrient loading may be incorporated by algae (phytoplankton and periphyton) but rapidly transferred to consumers (fish and macroinvertebrates) without increasing algal standing crop biomass or affecting water clarity.

Fish and macroinvertebrate species assemblages remain diverse. The data are not sufficient to allow quantitative comparisons for any of the biota through time. Grazers could have increased numerically, but the data available are not good enough to determine whether they have changed. There was a major change in trophic composition among invertebrates from organisms that gather particles from the streambed to those that filter them from the water during the period of record.

CHEMICAL WATER QUALITY

Turbidity

Turbidity was used as an index of water clarity. The data bases contained several measures of turbidity. Prior to the early 1980's, most agencies were using absorbance in the visible spectrum as a measure of turbidity; the units applied to these measures were Jackson Turbidity Units (JTU). Beginning approximately in 1980, there has been a gradual shift to use of nephelometric measures of turbidity, which are reported as Nephelometric Turbidity Units (NTU's). We have used absorbance values of turbidity (JTU's) as the primary measure of turbidity, since this appeared to be the most commonly reported value and thus was the largest data base available for comparing differences among stations. Only one station, USGS 07195000 on Osage Creek, had turbidity measurements recorded as NTU's.

The turbidity was generally high in the upper portions of the river basin and decreased longitudinally to the downstream stations (Table 7).

There was a significant temporal decrease in turbidity at USGS 07194800, 07195000, and 07195860 during the period of record. There was a highly significant increase in turbidity within Lake Frances (SR 0.5) reflecting the severe eutrophication status of this lake (Table 8). A highly significant temporal increase also existed in turbidity at SR 1, SR 3, SR 5, and USGS 07197000 on Baron Fork Creek.

Most of the median analyses showed either a slight or a significant decrease from the upstream to the downstream stations (Table 9. Except when comparing the stations above (USGS 07196500) and below (SR-6) the Tahlequah STP.

Overall, water in the Illinois River showed a higher level of turbidity in the upper reaches and tributaries with a significant decrease when comparing upstream versus downstream locations. Most of the mainstem river sampling locations exhibited no significant change in concentration of turbidity over time.

Table 7. Summary statistics for Illinois River sampling stations for turbidity.

STATION ID	n (months)	Turbidity (JTU's)		
		Mean	Median	SD
USGS 07194800	133	13.835	6.000	23.562
USGS 07195000*	70	8.402	4.000	10.354
USGS 07195400	ND	ND	ND	ND
SR 0.5	14	34.583	22.000	35.536
USGS 07195500	127	13.935	11.000	13.944
SR 1	64	11.815	6.000	15.227
SR 2	66	4.681	3.000	4.047
USGS 07195860	130	5.946	2.600	9.905
USGS 07196000	121	2.939	1.000	5.875
SR 3	66	5.476	3.000	7.646
SR 4	66	5.578	2.000	10.217
SR 4.5	14	34.976	4.250	104.211
SR 5	66	6.176	2.750	11.449
USGS 07196500	128	5.967	3.000	10.387
SR 6	62	6.595	2.000	12.376
SR 6.3	10	18.783	5.500	34>028
USGS 07197000	128	3.363	1.000	10.489

* Units are NTU's at this station
ND = No Data

Plots of monthly average turbidity with slope estimates and median turbidity comparison plots are in Appendix I.

Table 8. Trend tests for turbidity			
Station	Kendall Tau Test Statistic	Seasonal Kendall Test Statistic	Seasonal Kendall Sen Slope Estimate (JTU/yr)#
USGS 07194800	-2.149***	-2.676***	-0.25000
USGS 07195000#	-2.996***	-2.394***	-0.37500
USGS 07195400	---	---	---
SR 0.5	2.977***	0.707	61.50000
USGS 07195500	0.907	1.213	0.30000
SR 1	1.408*	1.462*	0.75000
SR 2	1.262	1.254	0.33333
USGS 07195860	-1.695**	-1.845**	-0.07009
USGS 07196000	0.803	1.268	0.00000
SR 3	1.815**	1.548*	0.27500
SR 4	1.008	1.010	0.05000
SR 4.5	0.069	0.000	195.41667
SR 5	1.611*	1.515*	0.16667
USGS 07196500	0.589	-0.071	0.00000
SR 6	0.024	-0.275	0.00000
SR 6.3	1.393*	0.000	0.00000
USGS 07197000	1.912**	2.560***	0.01500

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

= units are NTU rather than JTU
Monthly averages used to calculate all statistics. The Kendall Tau Test was performed on deseasonalized data.

Table 9. Comparison of upstream vs downstream median concentration of turbidity.

Stations Compared Upstream vs Downstream	Wilcoxon Signed Rank Test Test Statistic	Seasonal Hodges-Lehmann Est. of Difference in Medians Turbidity (as JTU)
GS48 vs GS54	ID	ID
GS48 vs GS55	-2.809***	2.375
GS55 vs SR1	2.801***	-2.500
SR1 vs SR2	5.098***	-3.000
SR2 vs GS60	4.734***	-1.500
SR2 vs SR3	1.418*	-0.000
SR3 vs SR4	1.420*	0.000
SR4 vs SR4.5	-2.040***	1.042
SR4 vs SR5	-1.261	0.000
SR5 vs GS65	-0.005	0.000
GS65 vs SR6	-0.287	0.000
SR6 vs SR6.3	ID	ID

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

ID = Insufficient Data

Nonfilterable Residue

Another parameter used as an index of water clarity was the suspended particles retained by 0.45 micron filter and dried at 105 °C for 24 hours (EPA Storet 530).

The mean and median concentrations of suspended particles showed a pattern similar to that of turbidity, i.e., relatively higher concentrations in the upper portion of basin than in downstream areas. There were notable exceptions to this general trend. For example, the concentration of suspended materials in Lake Frances (SR 0.5) was the highest of all stations (Table 10). There were increases at SR 4.5 and SR 6, which appeared to be from point sources.

There was a slight, but significant (Kendall Tau, 90% CL) temporal decrease in suspended solids at USGS 07194800 during the period of record (Table 11). This was in agreement with the same trend noted with turbidity at this station. There was a highly significant increase in suspended solids within Lake Frances (SR-0.5) but again the period of record at this station was only 14 months.

Comparisons of median residue concentrations at upstream and nearest downstream stations showed a weak trend toward decreased concentrations going downstream (Table 12). A notable significant increase in median concentration was observed between USGS 07195400 and USGS 07195500. This is again evidence of the effect of Lake Frances on stream water quality below the lake. Median analysis also indicates an increase in median non-filterable residue concentration between SR 4 and SR 5.

Time series plots of monthly average non-filterable residue with slope estimates and graphic comparisons of median non-filterable residue are in Appendix J.

Table 10. Summary statistics for Illinois River sampling stations for non-filterable residue.

STATION ID	n (Months)	Non-filterable Residue (mg/l)		
		Mean	Median	SD
USGS 07194800	149	18.584	10.000	31.781
USGS 07195000	140	15.535	9.000	26.188
USGS 07195400	68	16.794	10.000	20.864
SR 0.5	14	50.256	32.500	55.978
USGS 07195500	106	30.297	21.000	41.485
SR 1	64	20.142	14.500	20.419
SR 2	66	11.513	7.250	18.922
USGS 07195860	107	9.794	5.000	15.535
USGS 07196000	106	6.720	3.000	14.124
SR 3	66	8.446	4.000	12.663
SR 4	66	9.054	5.000	15>780
SR 4.5	14	21.492	9.400	33.076
SR 5	66	14.087	6.000	24.407
USGS 07196500	106	13.879	7.000	27.912
SR 6	62	18.298	5.000	40.517
SR 6.3	11	33.697	6.750	59.578
USGS 07197000	106	5.847	2.000	11.457

Table 11. Trend Tests, Residue (T-NFLT)			
Station	Kendall Tau Test Statistic	Seasonal Kendall Test Statistic	Seasonal Kendall Sen Slope Estimate (mg/l/yr)
USGS 07194800	-1.663**	-1.369*	-0.11806
USGS 07195000	-0.274	-0.509	0.00000
USGS 07195400	-0.926	-1.357*	-0.50000
SR 0.5	2.977***	0.707	126.62500
USGS 07195500	-0.560	0.000	0.00000
SR 1	1.031	0.827	1.00000
SR 2	-0.304	-0.184	-0.12500
USGS 07195860	-0.302	0.577	0.00000
USGS 07196000	-0.470	-0.604	0.00000
SR 3	1.671**	1.169	0.61806
SR 4	1.350	1.662**	0.50000
SR 4.5	0.069	0.000	56.89167
SR 5	1.876**	1.238	0.50000
USGS 07196500	0.379	-0.093	0.00000
SR 6	0.182	0.807	0.50000
SR 6.3	1.873**	0.000	0.71289
USGS 07197000	0.186	0.096	0.00000

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

Monthly averages used to calculate all statistics. The Kendall Tau Test was performed on deseasonalized data.

Table 12. Comparison of upstream vs downstream median concentration of non-filterable residue.

Stations Compared Upstream vs Downstream	Wilcoxon Signed Rank Test Test Statistic	Seasonal Hodges-Lehmann Est. of Difference in Medians Non-filterable Residue (mg/l)
GS48 vs GS50	2.388***	-1.000
GS48 vs GS54	-1.743**	1.000
GS54 vs GS55	-3.318***	6.000
GS55 vs SR1	2.013***	-2.000
SR1 vs SR2	4.682***	-6.000
SR2 vs SR3	2.444***	-2.000
SR3 vs SR4	0.193	0.000
SR4 vs SR4.5	-1.490*	1.233
SR4 vs SR5	-3.126***	1.417
SR5 vs SR6	-0.264	-0.000

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

CHLOROPHYLL

As noted in the Objective II report on the completeness and quality of data, information regarding chlorophyll _a_ (Chl _a_) levels and algal abundance in the Illinois River is relatively sparse. Only six papers, reports, or data sets contain any Chl _a_ data, and two of these deal solely with periphyton Chl _a_, data of little use in evaluating water clarity changes. Of the remaining four sources, two deal specifically with Lake Frances (US EPA 1977, Soballe and Threlkeld 1985) and two with the river proper (Terry et al. 1984, USACE 1987). Similarly small numbers of algal abundance and community composition studies are available. Two questions of central importance in our examination of Illinois River chlorophyll/algal data are:

1. Do planktonic chlorophyll or algal abundances contribute to water clarity problems in the river?

2. Have chlorophyll levels, algal densities, or species compositions changed over the period of record?

In this Objective III report, we used data discussed in our Objective II report to analyze historical changes that have occurred in Illinois River and Lake Frances Chl _a_ levels and algal population/community dynamics, with respect to the effect these changes may have had on water clarity.

Illinois River Chlorophyll

The STORET data set in USACE (1987) contains all but three of the 417 total Chl measurements available on the Illinois River. With the exception of eight concentrations reported for station AR06 (RM 114.5) during 13 Jun 77 to 17 Aug 82, the STORET data cover the period 29 Mar 84 to 30 Sep 86, although not all stations were sampled over the complete period. Figure 3 presents the mean, maximum, and minimum Chl _a_ values for each station over the entire 1977-86 period of STORET record. This figure illustrates the difficulty in analyzing Chl trends along the river reach, as the range in values at most stations spans two orders of magnitude. Mean pigment values at most of the stations (Figure 4) exceeded 5 ug/l, with maximal values at SR0.5 (in Lake Frances), USGS 1955 (immediately below Lake Frances), and SR4 (19 miles downstream of Lake Frances).

The data in Figures a and b are of limited use in examining historical trends in pigment levels. Figure 5 contains the STORET data for summer from 1981-1986, the only season where data are available for all years. No readily recognizable historical trends are evident in these data. Seasonal analyses of pigment level changes in each water year and at station available were made (e.g., Figure 6), but such plots only served to underscore the high degree of seasonal variation in pigment levels typically found in any aquatic system.

High levels of Chl *a*, associated with dense populations of planktonic algae, clearly reduce the transparency of aquatic systems. Vollenweider (1968) reviewed the literature on the relationship between chlorophyll levels and eutrophication in lentic freshwater systems and classified mesotrophic systems as having mean annual Chl *a* concentrations of 1-15 ug/l, whereas eutrophic systems possessed between 5 and 140 ug/l. This index cannot be directly transferred to lotic systems in that streams and rivers generally possess much less suspended algae per increment nutrient loading than lakes due to canopy limitations, non-biogenic turbidity, and washouts.

To our knowledge, no empirical model relating chlorophyll levels alone to water transparency in flowing water systems has been published. Nonetheless, the Vollenweider trophic classification index provides some useful objective criteria in examining the Illinois River Chl *a* data set. For example,a lake with a mean annual Chl *a* level of between 5 and 10 ug/l would be borderline eutrophic, by definition a state in which there is at least a slightly visible greenish caste to the water. At 15 ug/l Chl *a* and above, a clearly eutrophic system, planktonic densities are usually high enough to reduce water clarity significantly, regardless of other turbidity factors.

The frequency at which STORET Chl *a* concentrations at each Oklahoma sampling station equalled or exceeded 5, 10, and 15 ug/l during water years 1984, 1985, and 1986, expressed as a percentage of all measurements at each station, are shown in Figures 5 through 7. This ranking provides some insight into the relative frequency at which an observer would characterize a given river site as eutrophied. For the river system as a whole, pigment levels of 5 ug/l occurred roughly 40% of the time in 1985 and more than 50% of the time in 1986. In 1985, levels at or above 15 ug/l were found about 40% of the time at SR0.5 and USGS 1955, in and immediately downstream of L. Frances. In 1986, all Oklahoma stations but SR1 (RM 104) had at least some measurements that fell within the 15 ug/l category.

While not shown in Figures 5 through 7 due to the small number of measurements taken, sampling stations on the Arkansas portion of the river reach (AR06, 1977-82, N=8; AR61, AR63, AR40, 1985 N=7 each) contained 43, 18, and 7% of their values in the 5, 10, and 15 ug/l concentration classes, respectively. This proportion is similar to that noted in most of the stations on the Oklahoma portion of the river during 1986.

A comparison of frequency distributions between 1985 and 1986 suggest that chlorophyll levels increased over the two year period. Since the only continuous period of record for pigment data occurred between early 1984 and late 1986, this remains the only time frame in which historical trends can be computed for the Oklahoma portion of the river.

Using the Kendall Tau test statistic, it is possible to analyze multi-year data sets and determine whether statistically significant trends are apparent during the period of record. Trend analyses and annual box and whisker plots were performed on Chl a data sets from the SR-0.5, USGS 1955, SR-2, SR-3, SR-4, SR-4.5, SR-5, USGS 1965, SR-6.3, USGS 1960, and USGS 1970. USGS 1955, 1965, 1960, and 1970 sampling stations included data sets from March, 1984 through water year 1986. All scenic river stations had Chl a data sets no longer than 14 months. These analyses are shown in Figures 8-28. As the analyses indicate, in most cases a statistically significant change in Chl a content was detectable at Illinois River and major tributary sampling stations above Lake Tenkiller during the 3-year period of record available, even at the 20 % significance level. SR0.5, within Lake Frances did show an upward trend but the data were not statistically significant, even at the 20% significance level (See Table 14).

Similar analyses were conducted on the pooled data from Arkansas sampling stations for the 1977-1985 period of record (Fig. 31). The Arkansas data set was insufficient to support a valid Kendall Tau test and a linear regression model was used instead. An ANOVA conducted on 1985 data collected at AR40, AR61, and AR63 indicated that mean values at each site were statistically dissimilar ($P < 0.05$). These mean values were thus treated as separate data points and were analyzed along with STORET mean Chl a values from station AR06 in 1977-1982 and one measurement each conducted at RM 138.1, 124, and 115.5 during Aug 1981 in Terry et al. (1984).

As in similar analyses of Oklahoma data, the Chl a levels trend downward over the period but the trend is not statistically significant, even at the 20% level. The trend disappears entirely if the two data points from 1980 are deleted from the linear regression computation.

Lake Frances Chlorophyll

Table 13 summarizes the Lake Frances Chl a data in USEPA (1977) and Soballe and Threlkeld (1985). The yearly mean pigment levels in the latter paper suggest that Lake Frances became much more eutrophic over the period 1974 to 1981-82. However, this conclusion may in fact be incorrect in that the sampling periods reported in the 1974 data set coincide with the times of phytoplankton community crashes noted by Soballe and Threlkeld. Thus, the 1974 data set may be more reflective of yearly minimum pigment levels rather than being comparable to the full year mean values reported by Soballe and Threlkeld (see discussion in next section).

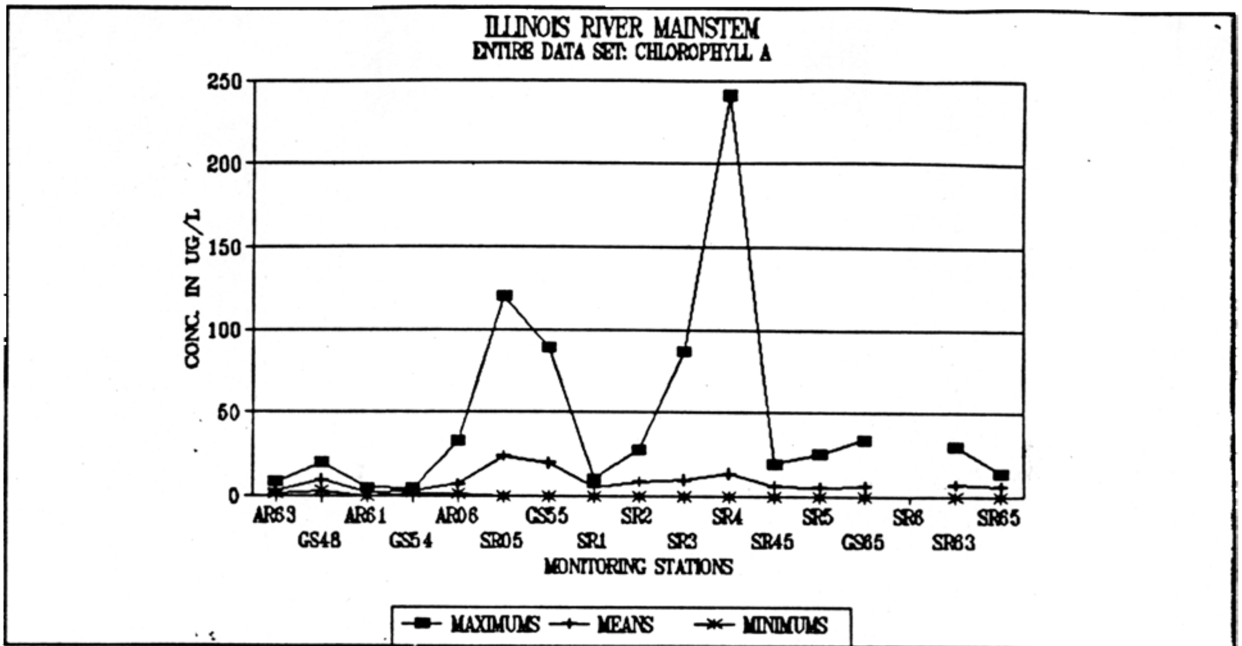

Figure 3. Chlorophyll a maximum, mean, and minimum concentrations for the entire period of record.

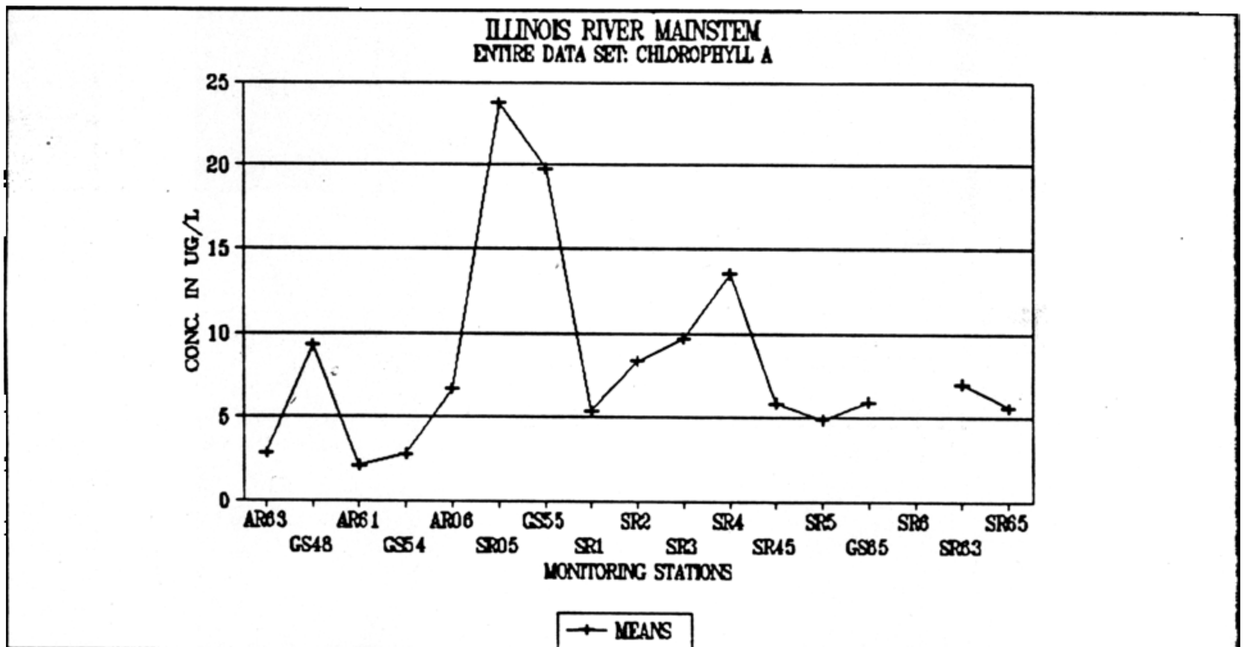

Figure 4. Chlorophyll a mean concentrations for the entire period of record.

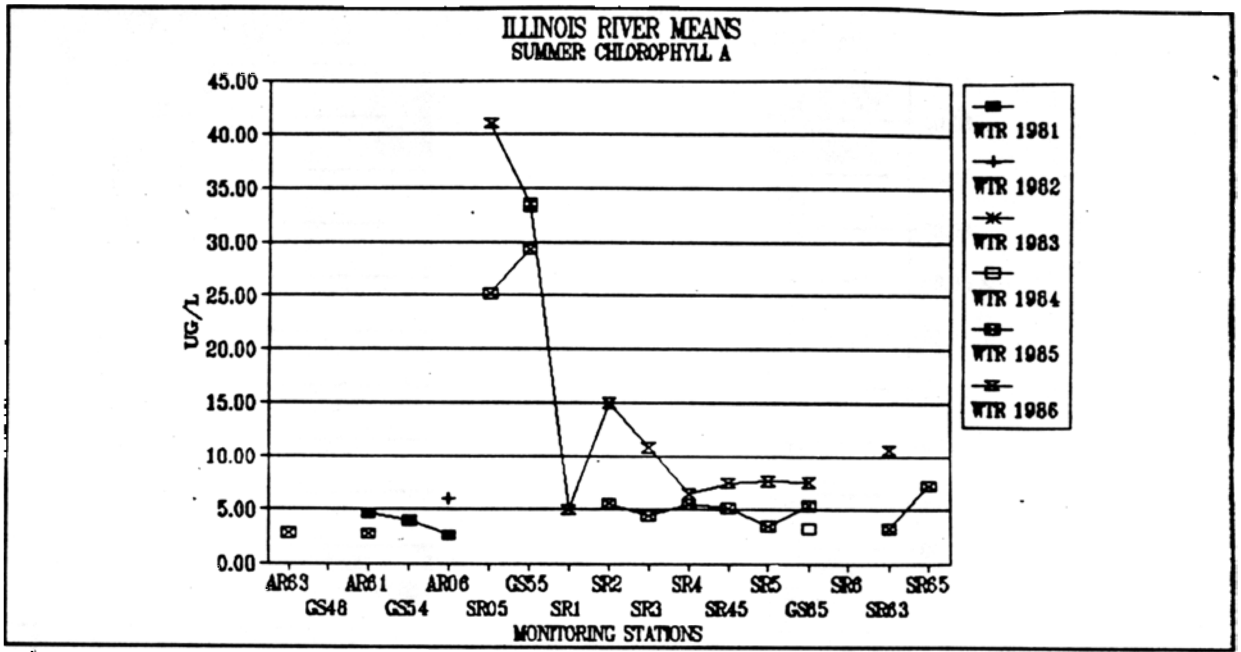

Figure 5. Chlorophyll a Summer mean concentrations.

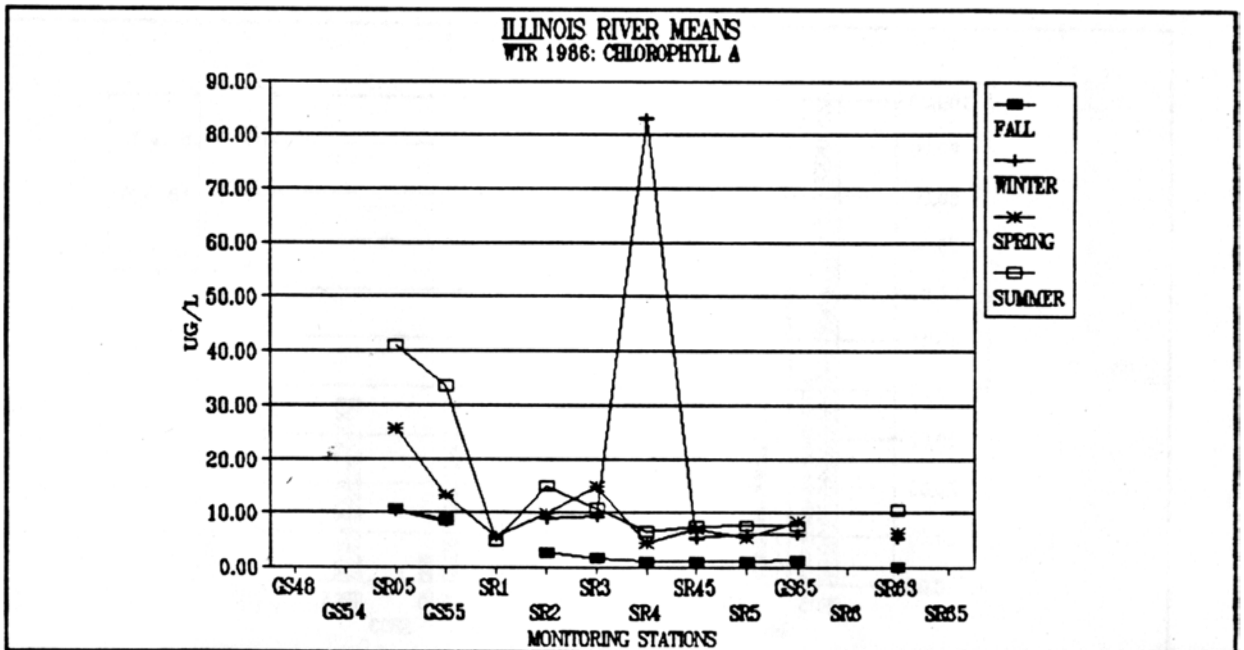

Figure 6. Chlorophyll a seasonal mean concentrations in Water Year 1986.

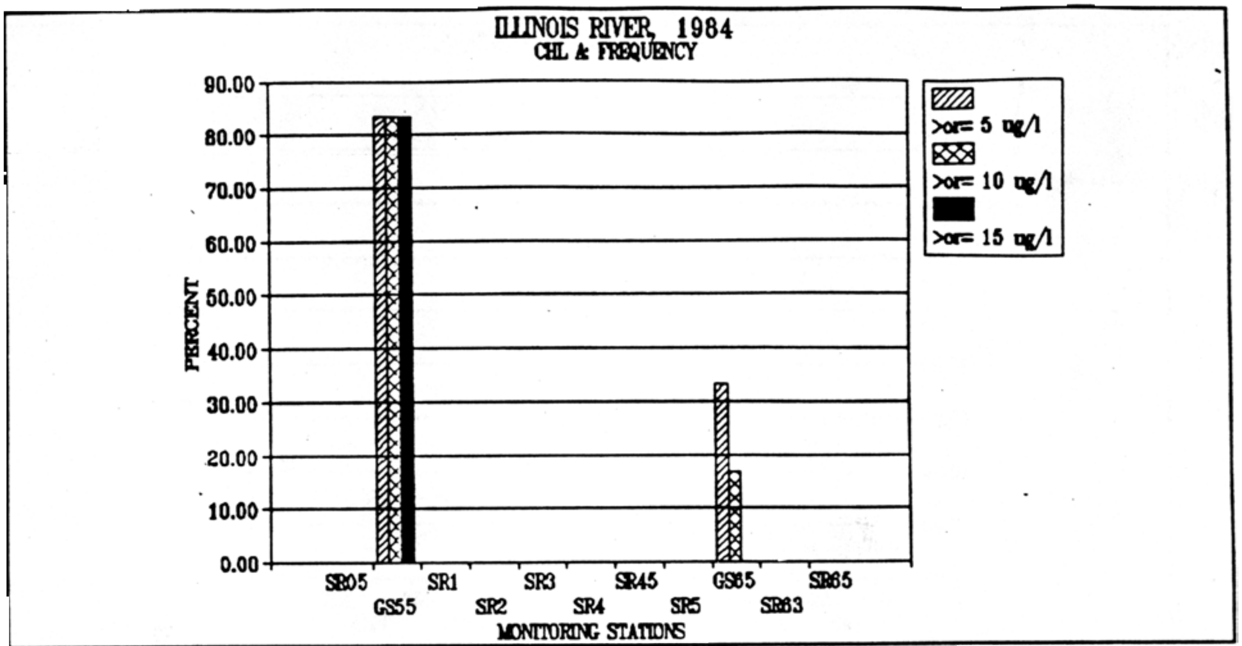

Figure 7a. Chlorophyll a concentration frequency for Water Year 1984.

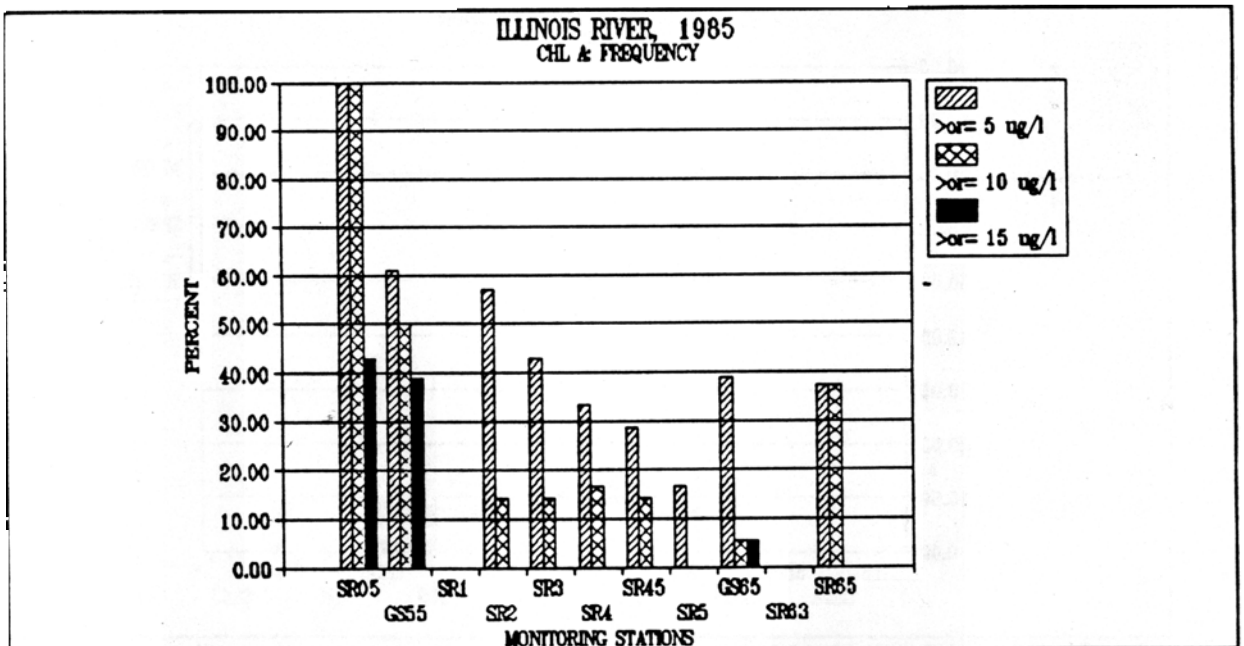

Figure 7b. Chlorophyll a concentration frequency for Water Year 1985.

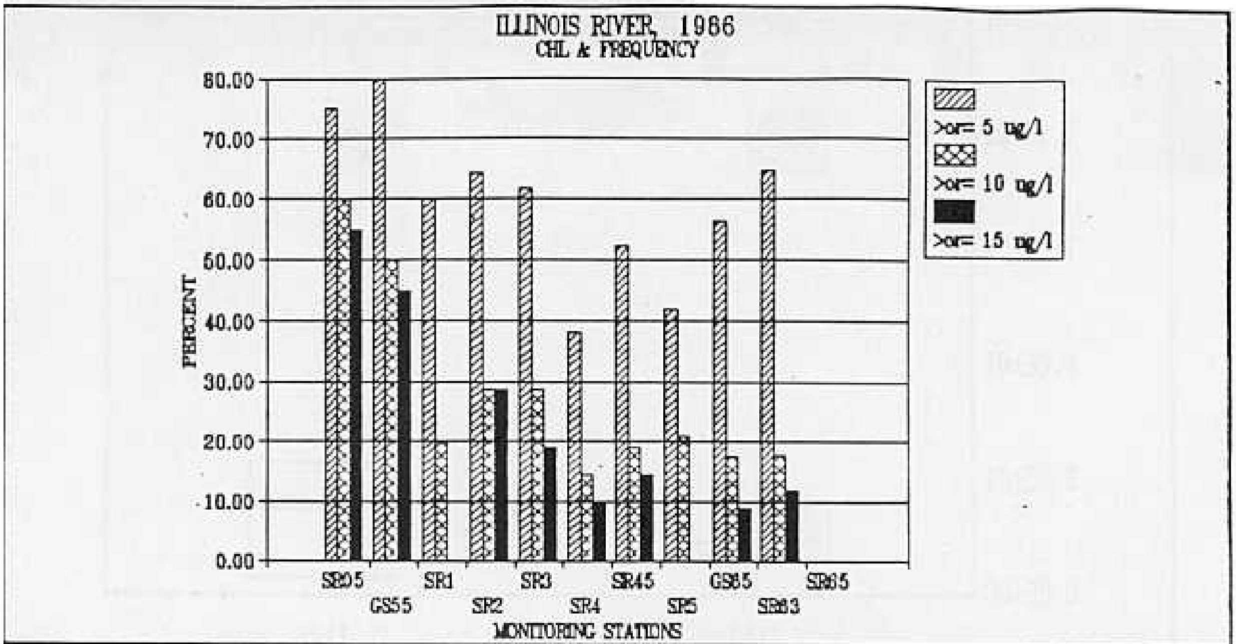

Figure 8. Chlorophyll a concentration frequency for Water Year 1986.

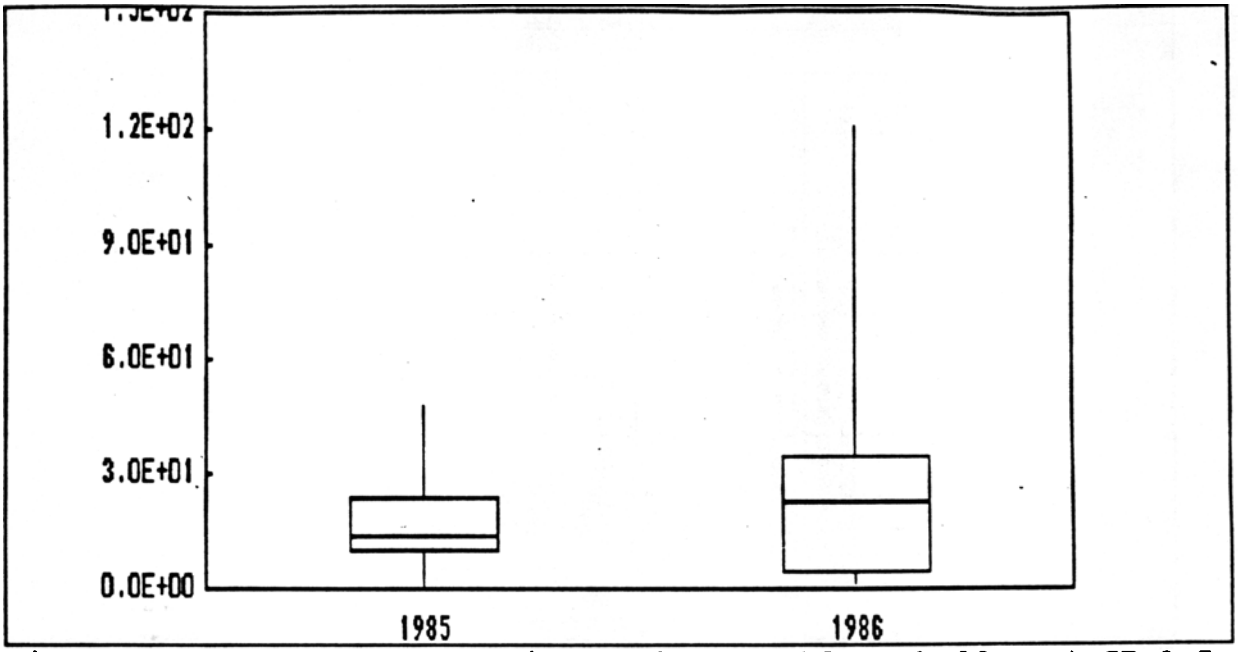

Figure 9. Annual box and whisker plot of chlorophyll a at SR 0.5.

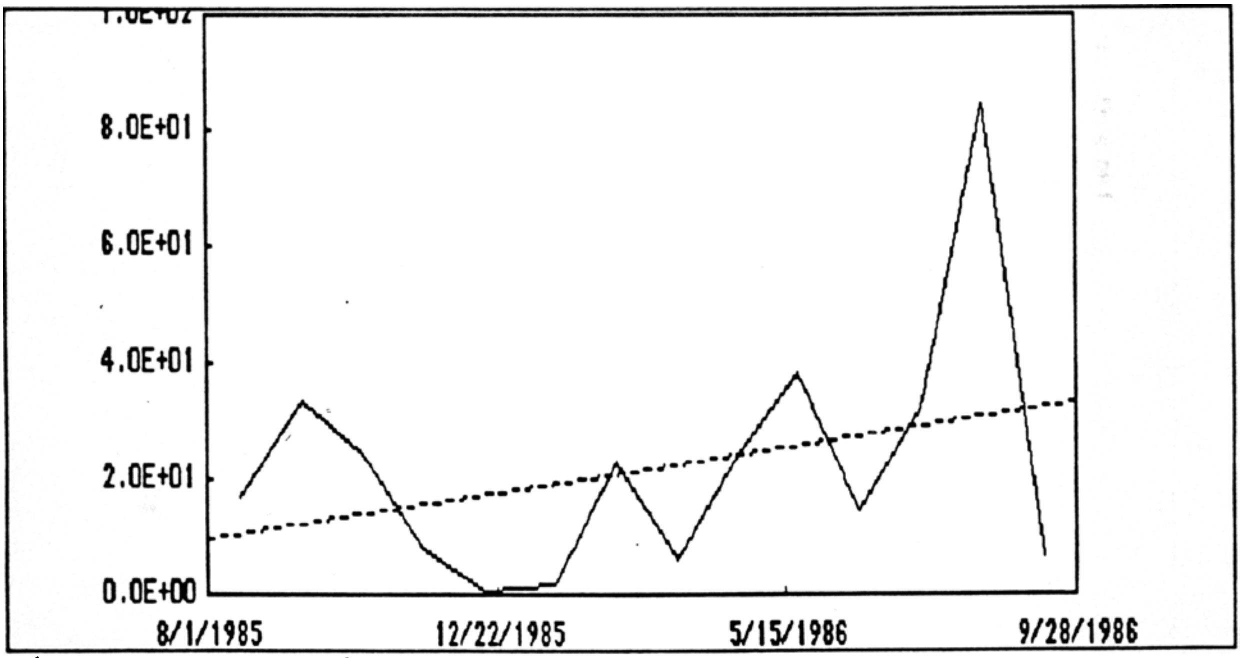

Figure 10. Chlorophyll a trend at SR 0.5.

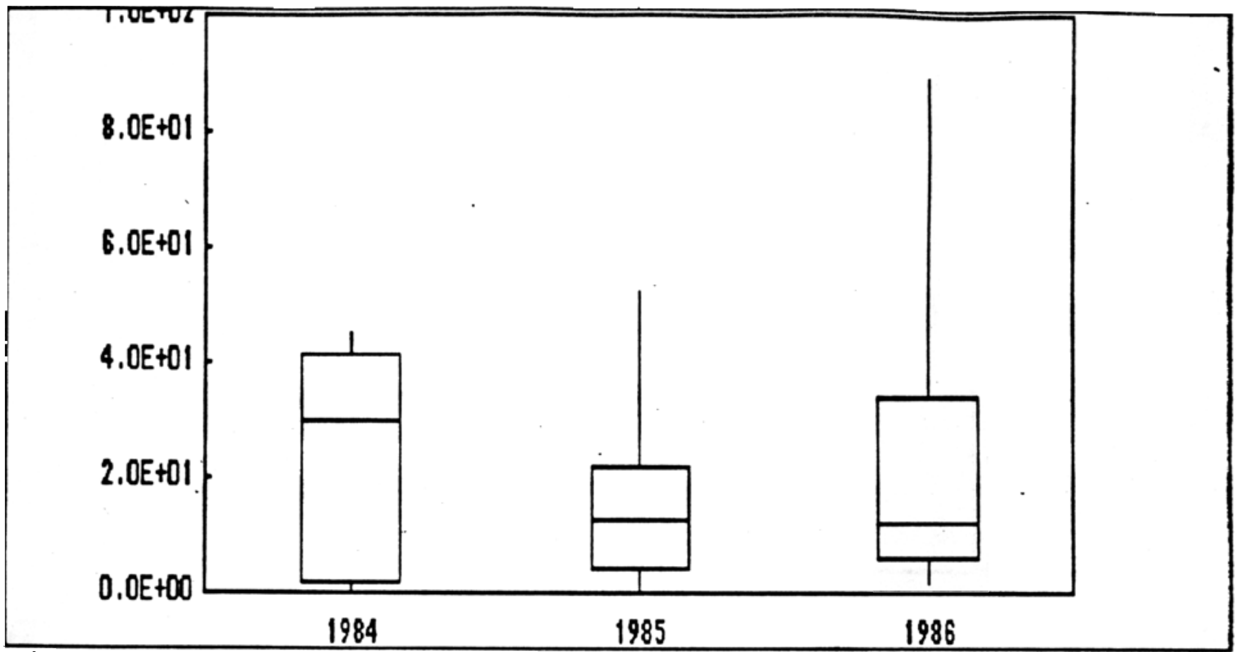

Figure 11. Annual box and whisker plot of chlorophyll a at USGS 07195500.

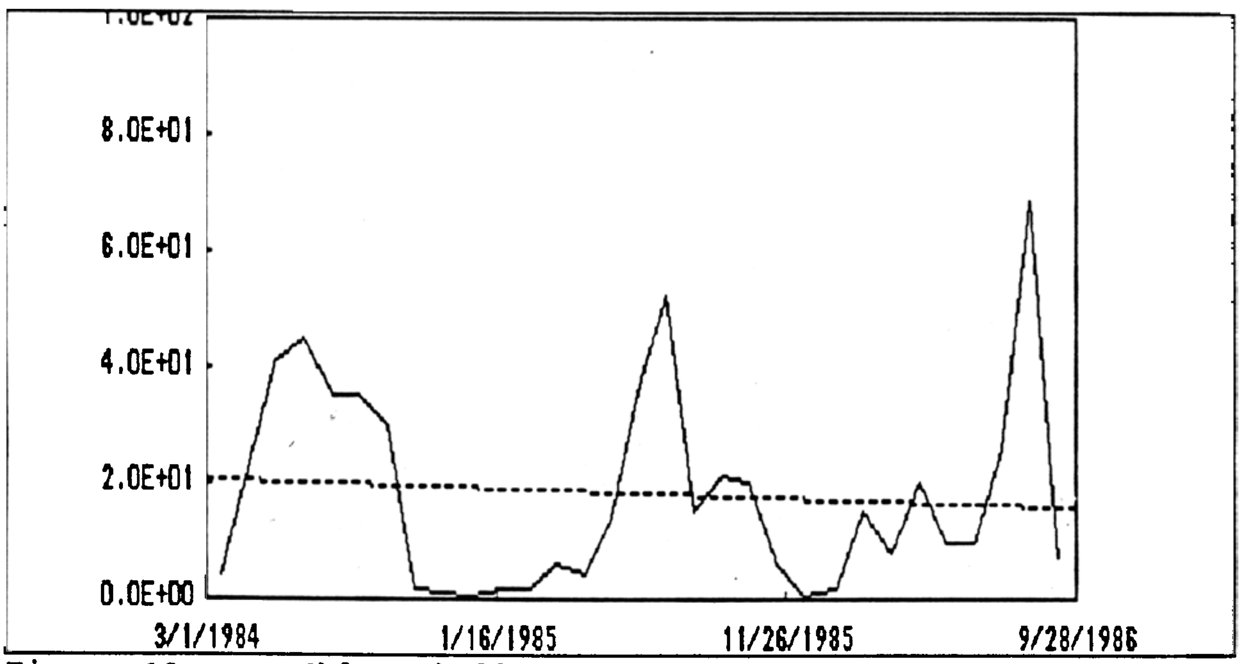

Figure 12. Chlorophyll a trend at USGS 07195500.

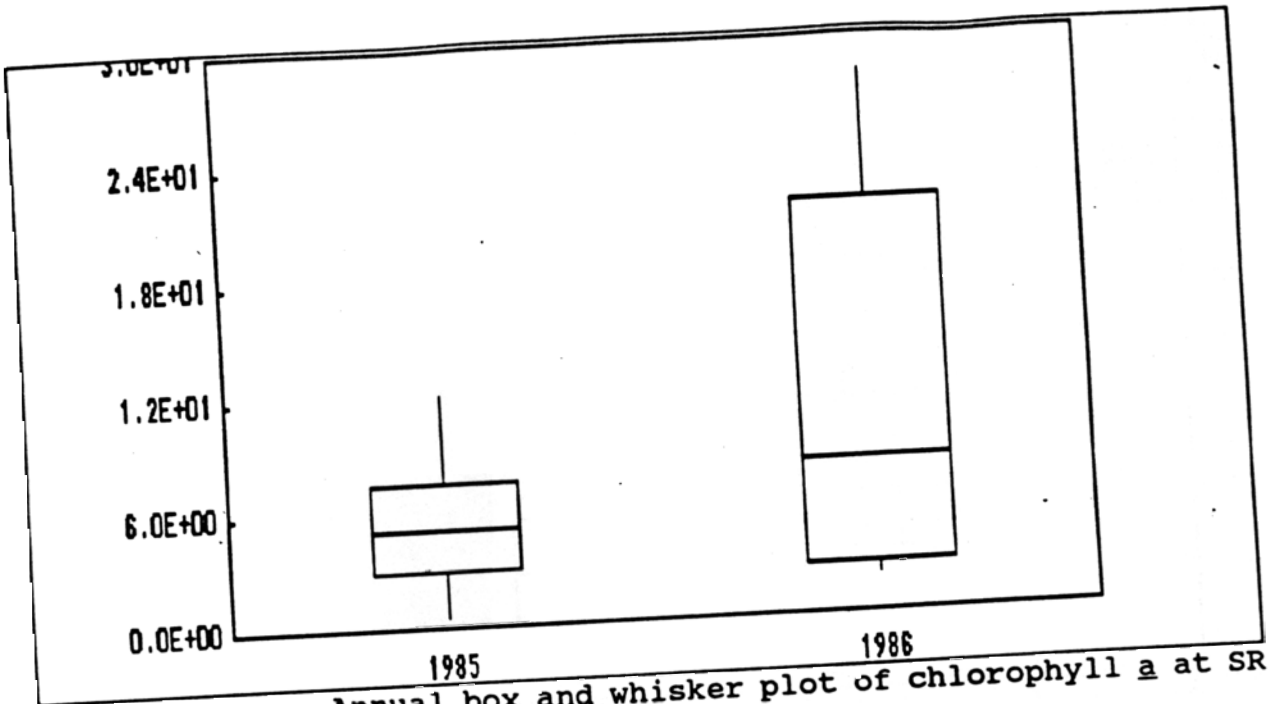

Figure 13. Annual box and whisker plot of chlorophyll a at SR 2.

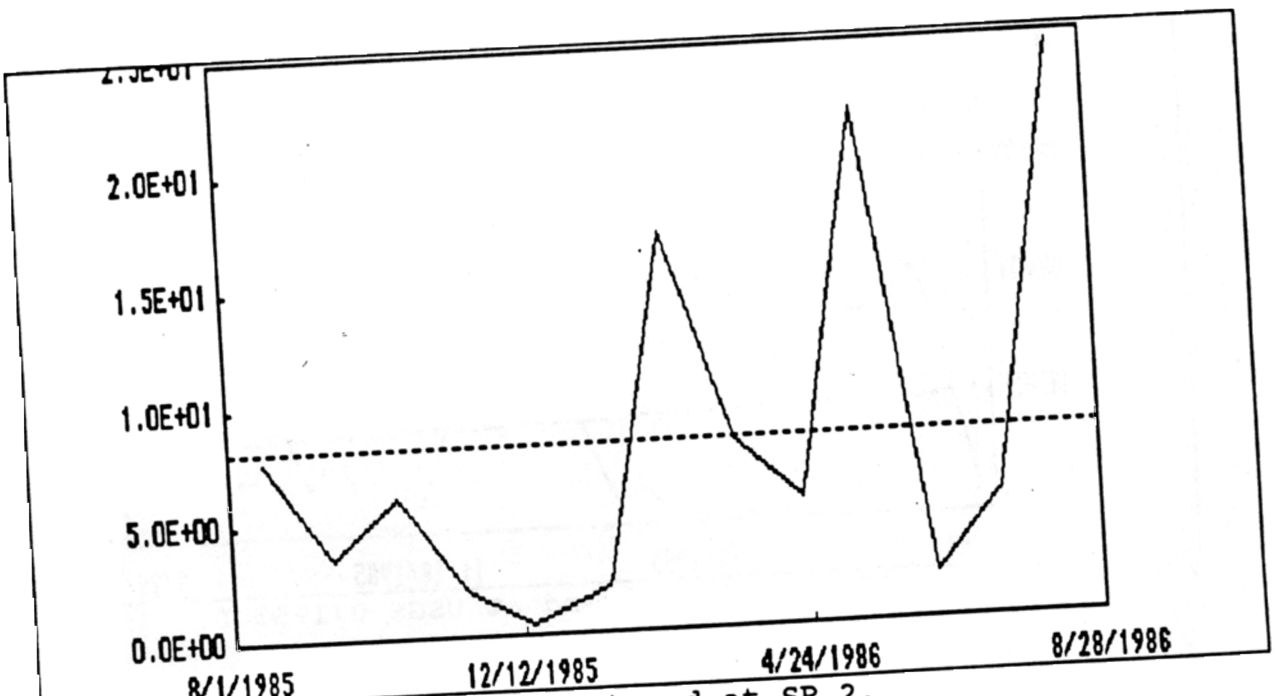

Figure 14. Chlorophyll a trend at SR 2.

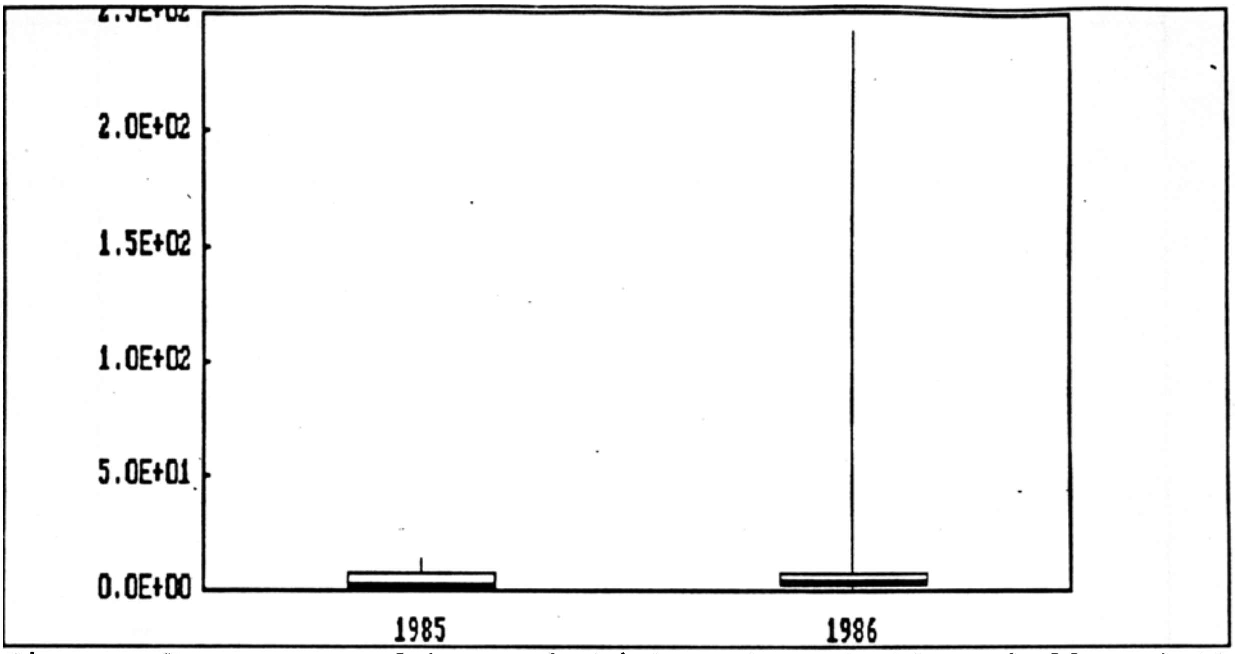

Figure 17. Annual box and whisker plot of chlorophyll a at SR 4.

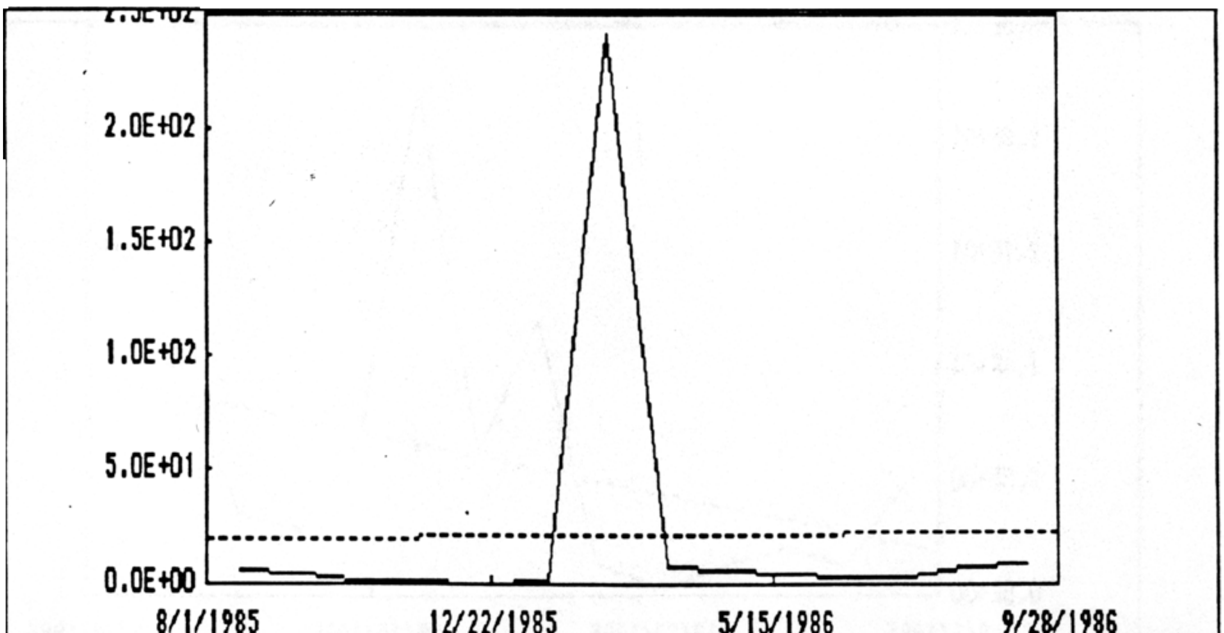

Figure 18. Chlorophyll a trend at SR 4.

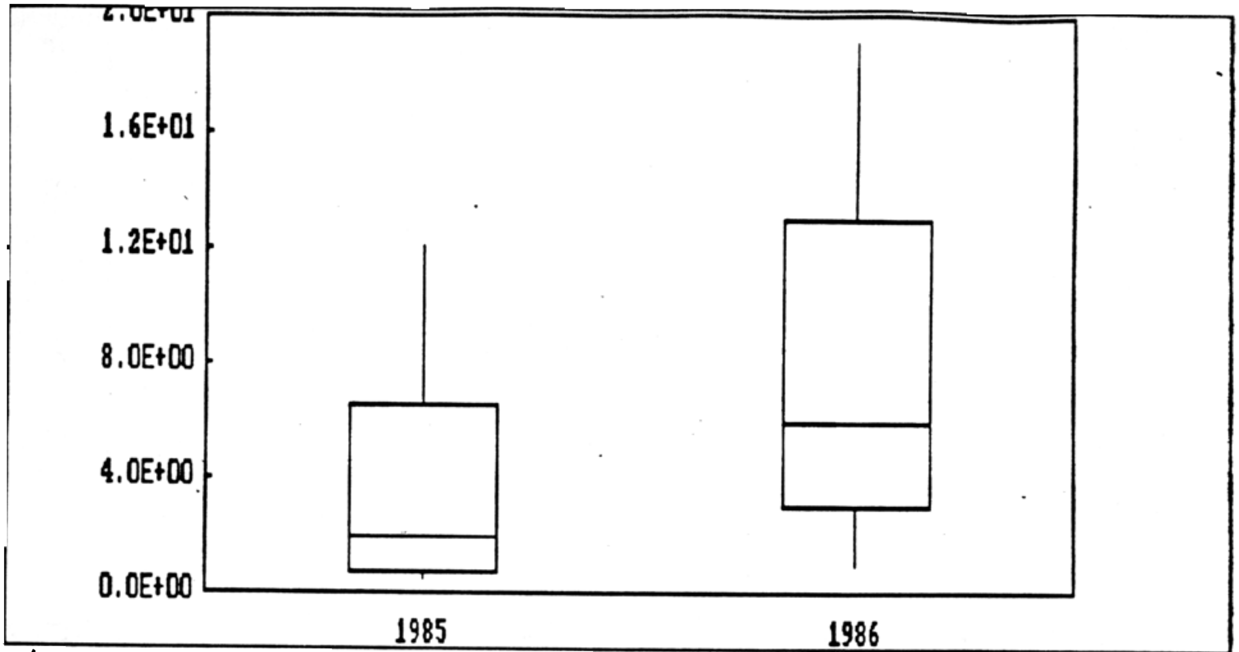

Figure 19. Annual box and whisker plot of chlorophyll a at SR 4.5.

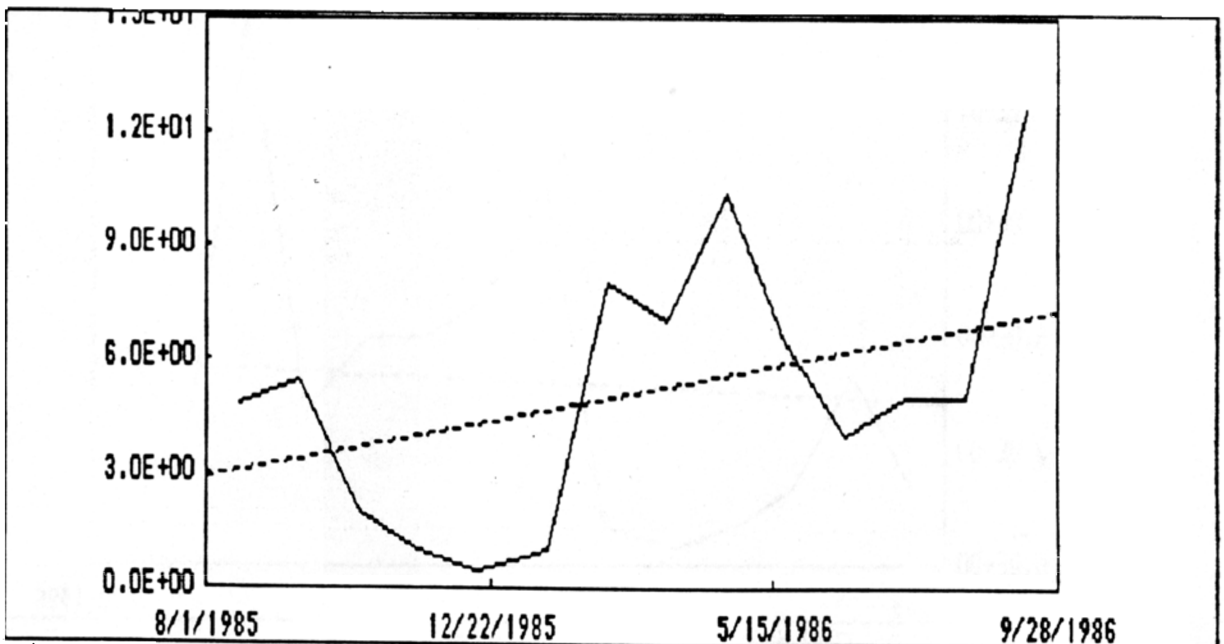

Figure 20. Chlorophyll a trend at SR 4.5

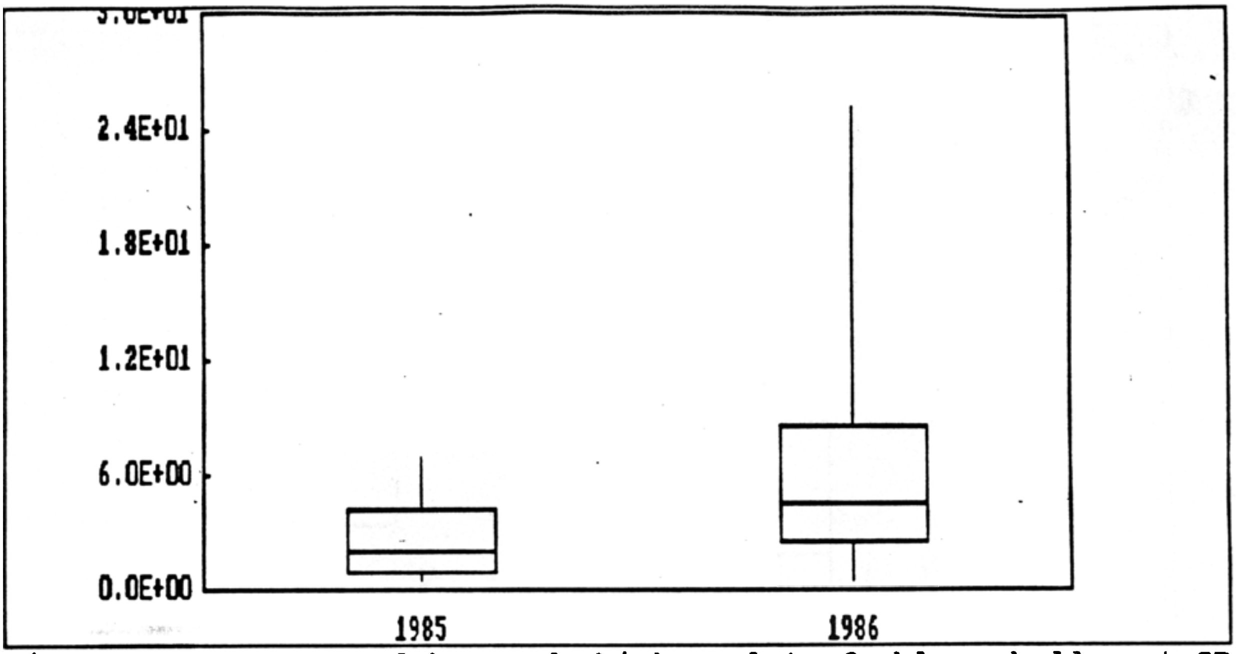

Figure 21. Annual box and whisker plot of chlorophyll a at SR 5.

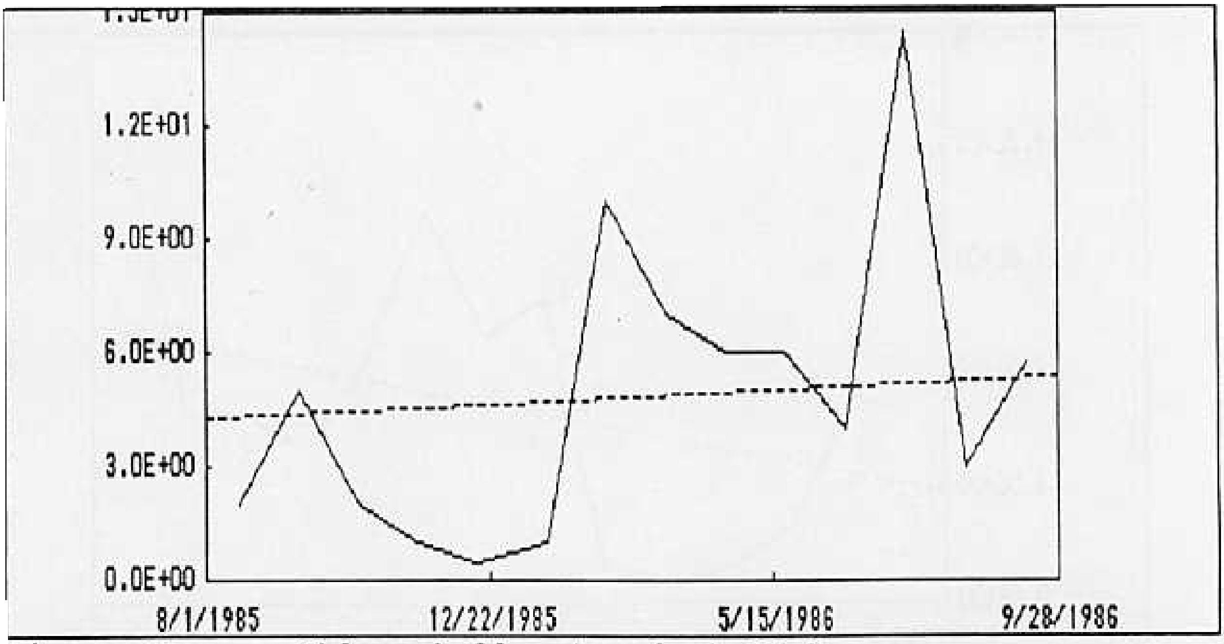

Figure 22. Chlorophyll a trend at SR 5.

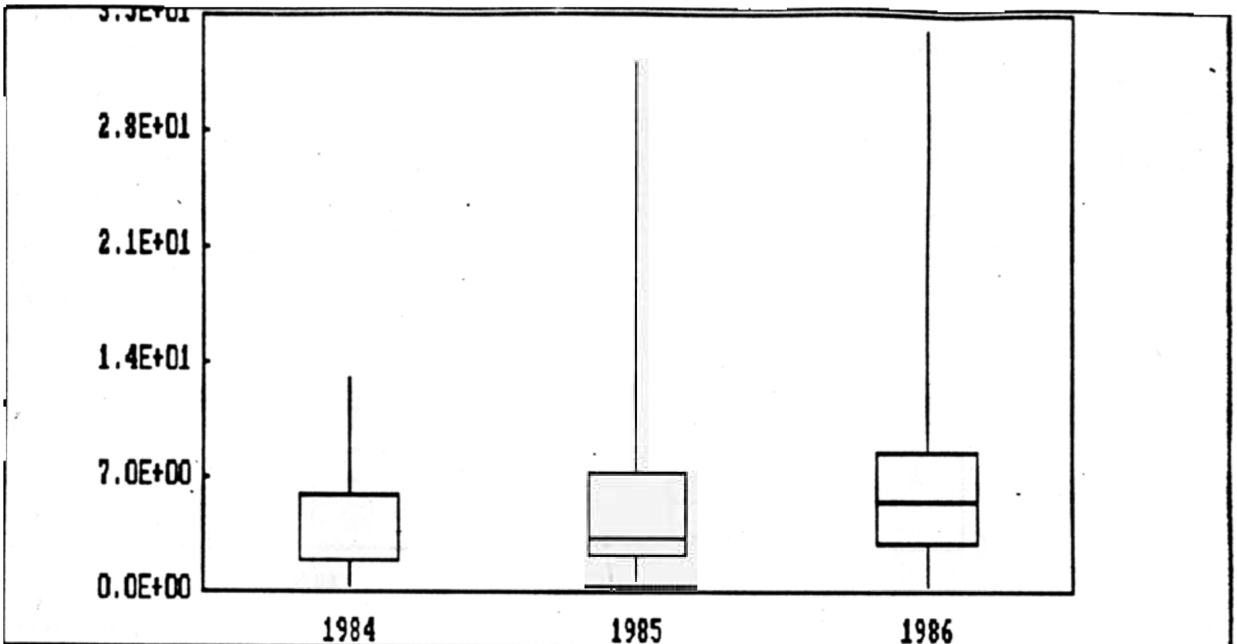

Figure 23. Annual box and whisker plot of chlorophyll a at USGS 07196500.

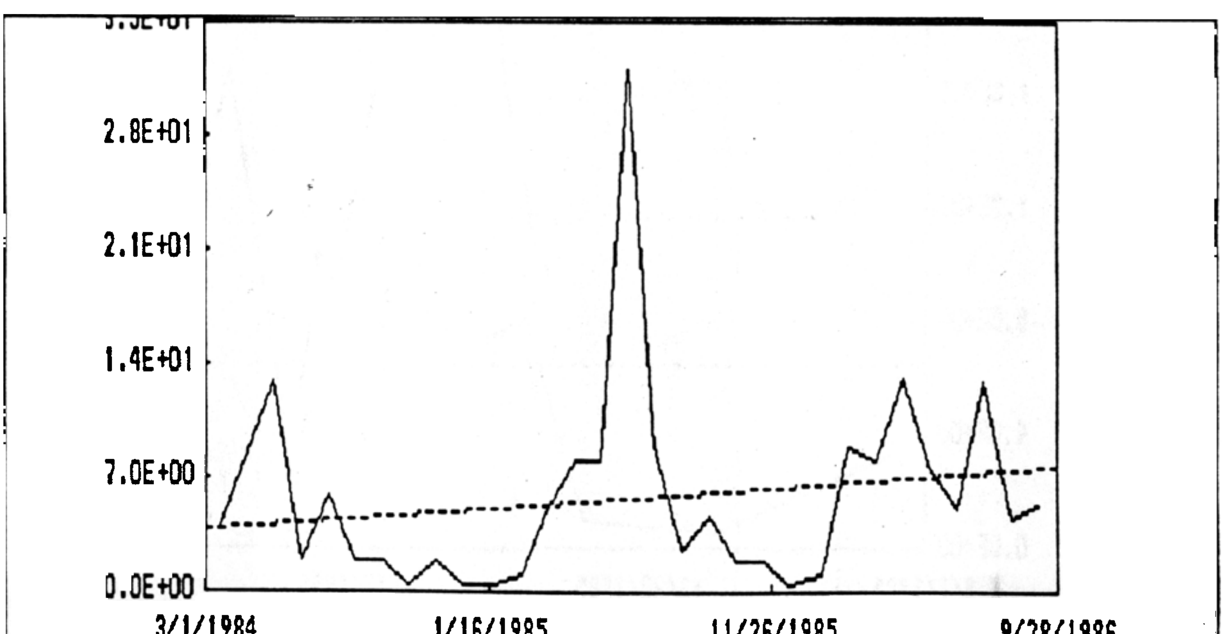

Figure 24. Chlorophyll a trend at USGS 07196500.

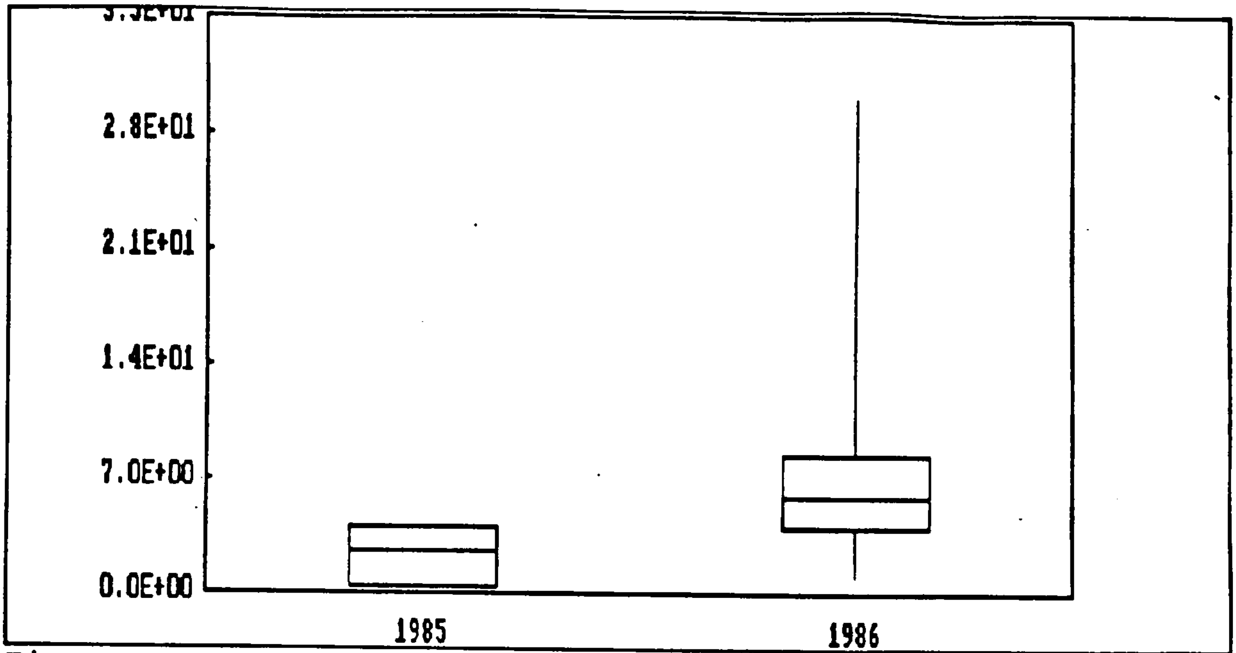

Figure 25. Annual box and whisker plot of chlorophyll a at SR 6.3.

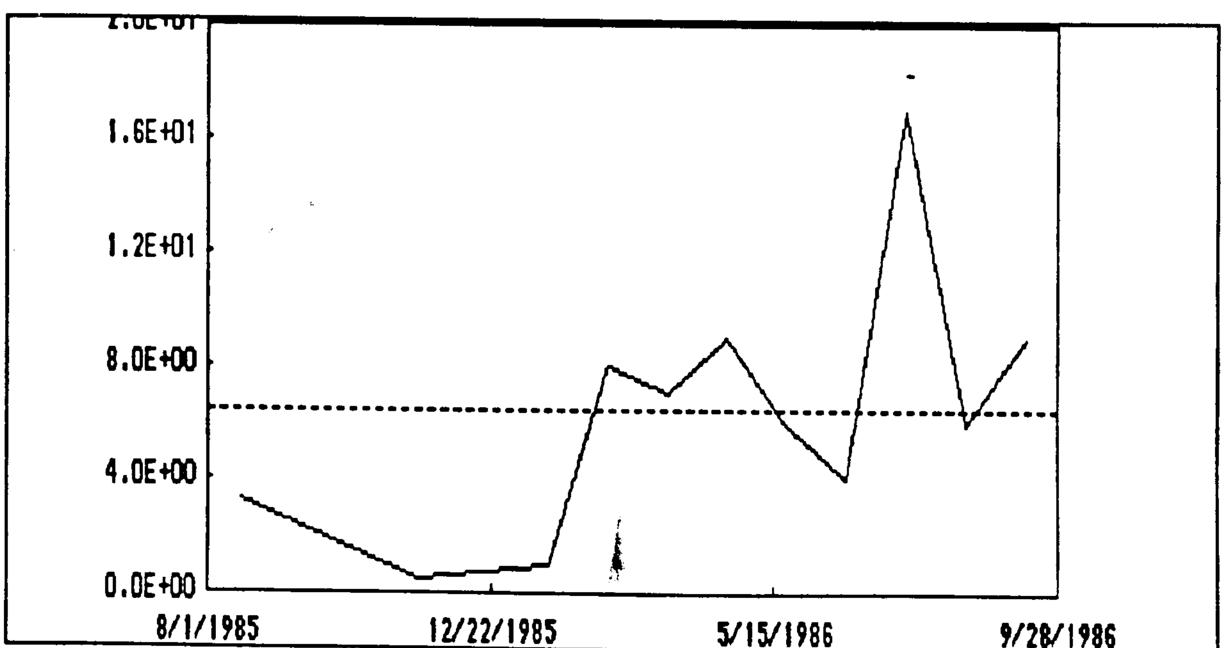

Figure 26. Chlorophyll a trend at SR 6.3.

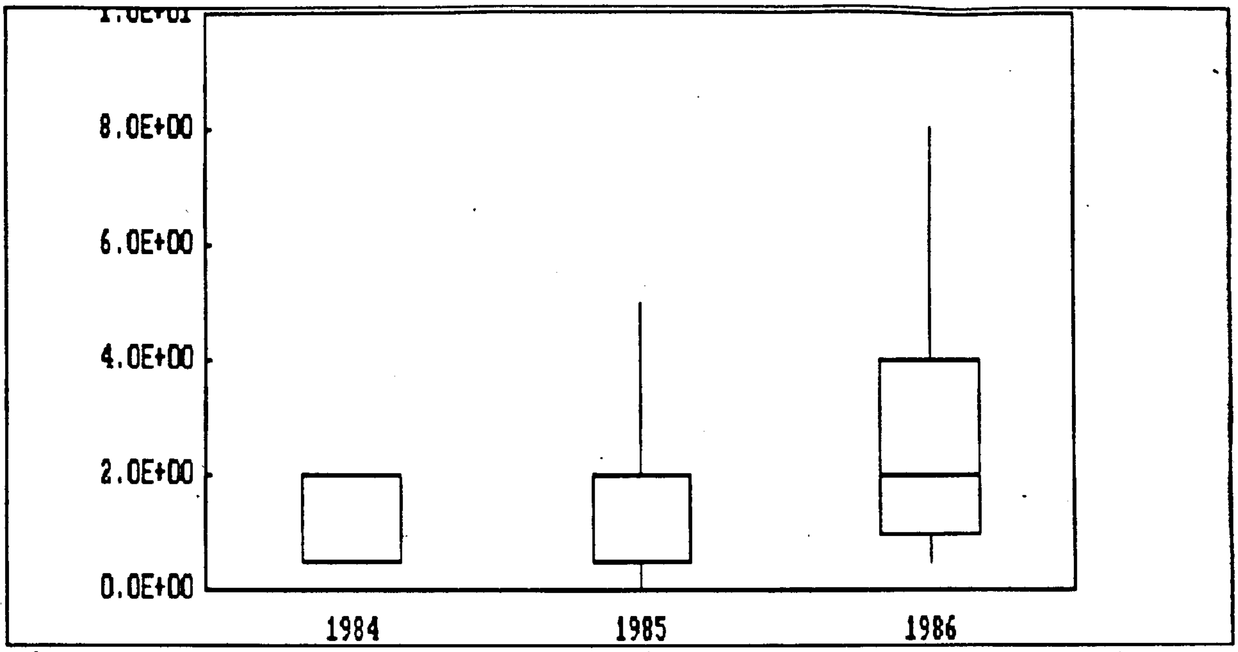

Figure 27. Annual box and whisker plot of chlorophyll a at USGS 07196000.

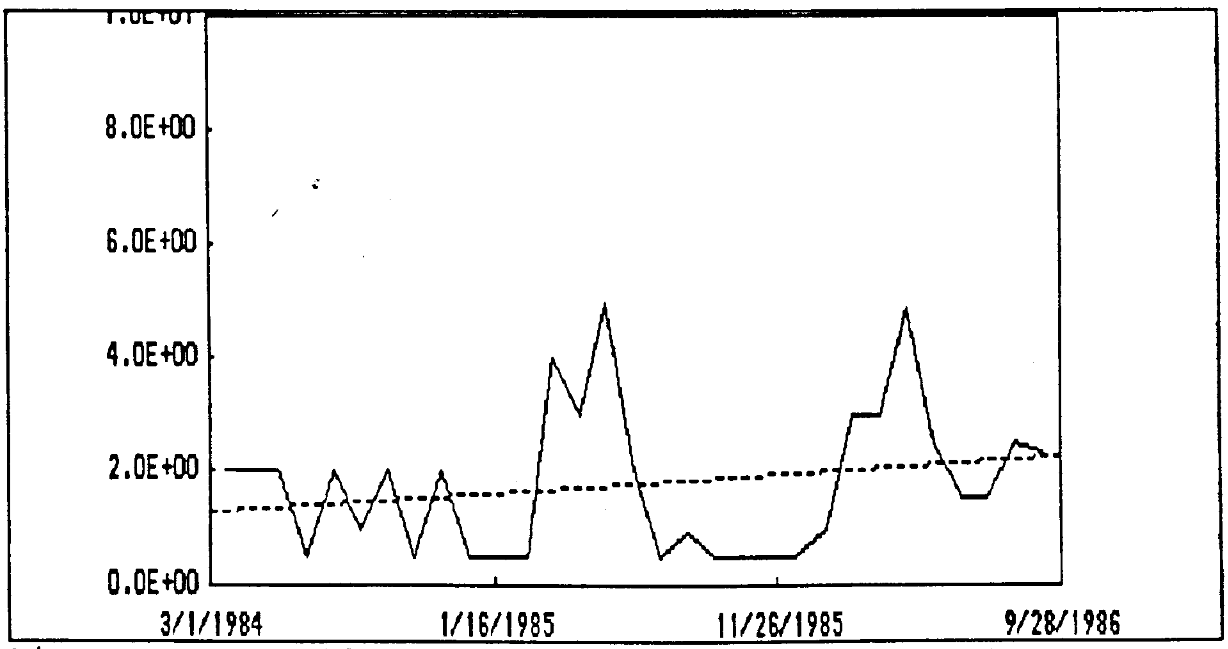

Figure 28. Chlorophyll a trend at USGS 07196000.

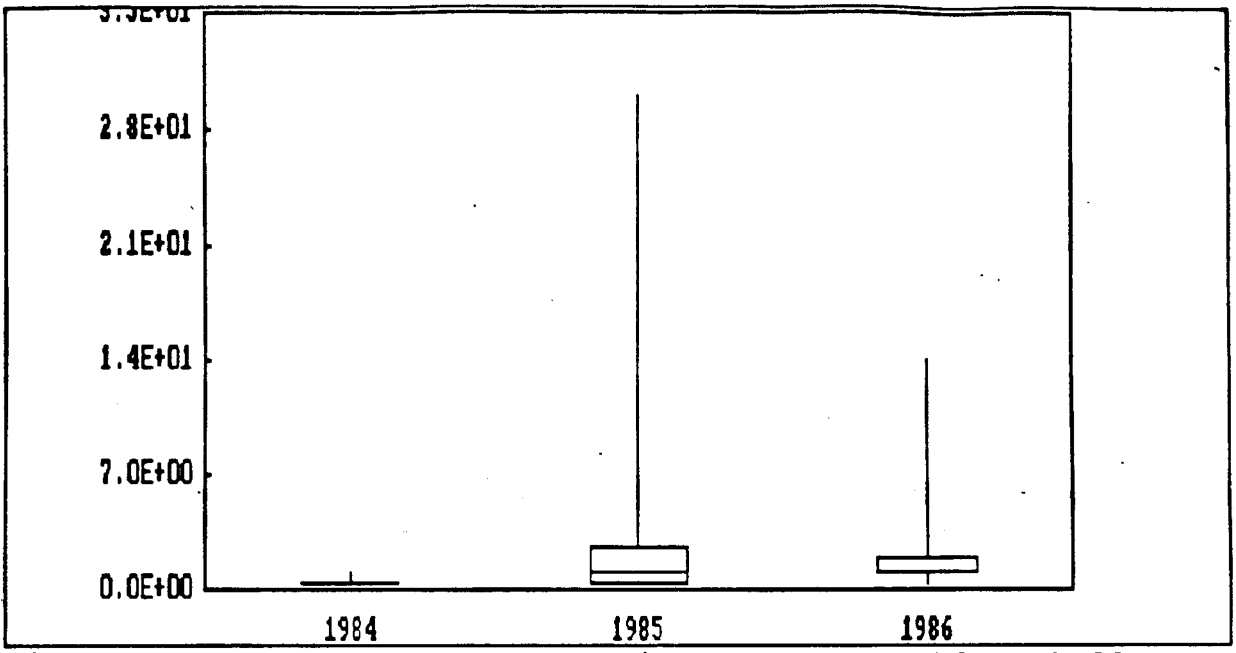

Figure 29. Annual box and whisker plot of chlorophyll a at USGS 07197000.

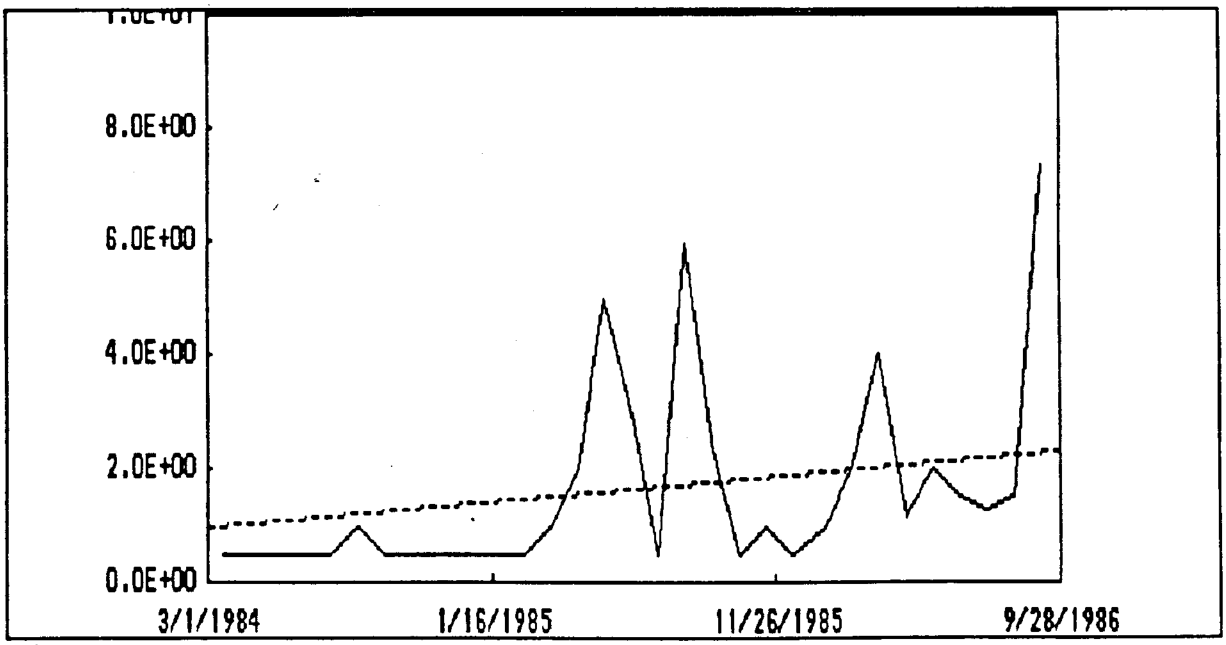

Figure 30. Chlorophyll a trend at USGS 07197000.

Figure 31. Chl a values for upper Illinois River, using STORET values for AR06, AR40, AR61, and AR63, and values from Terry et al. (1984) for RM 138.1, 124, and 115.5.

Regression equation for mean values in each year, $y=73.87a-0.81b$, $r^2=0.14$, $0.5>p>0.2$. Equation with 1980 data deleted $y=25.07a$, $r^2=0.06$, $p>0.5$.

Table 13. Lake Frances Chl a data.

1974 (USEPA 1977)
Sampling dates (4/3/74; 6/14/74; 10/18/74)
Lake proper only
Mean (Range) = 8.0 ug/l (0.1 - 17.6)

1981-82 (Soballe and Threlkeld 1985)
Mean yearly values Oct 81 - Oct 82
1) Illinois River above Lake Frances 4 ug/l
2) Lake proper (3 stations)
Mean (Range) 26 ug/l (5-37)
3) Illinois River below Lake Frances 39 ug/l

Table 14. Trend test results, chlorophyll a.

Station	Kendall Tau Test Statistic	Seasonal Kendall Test Statistic	Seasonal Kendall Sen Slope Estimate (ug/l/yr)
SR 0.5	0.069	0.000	20.35000
USGS 07195500	-0.626	-0.196	-2.00000
SR 2	2.161***	0.000	0.00000
SR 3	2.977***	0.707	9.15667
SR 4	2.977***	0.707	2.70000
SR 4.5	2.977***	0.707	3.68333
SR 5	2.977***	0.707	0.88750
USGS 07196500	2.751***	2.550***	1.50000
SR 6.3	1.873**	0.000	0.00000
USGS 07196000	1.987***	0.981	0.37500
USGS 07197000	2.183***	2.116***	0.50000

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

Monthly averages used to calculate all statistics. The Kendall Tau test was performed on deseasonalized data.

The pigment data available for Lake Frances and the river sampling station USGS 1955 immediately downstream suggests that Lake Frances is highly eutrophied and does serve as a source of planktonic turbidity immediately below the lake. As discussed in the next section, however, phytoplankton population and community analyses also suggest that this "washout" effect diminishes rapidly downstream, and that elevated pigment levels found at station SR4, for example,were the result of autochthonous production and not upstream export.

PHOSPHORUS

Total Phosphorus

The primary objective was to evaluate spatial and temporal changes in concentration of total phosphorus in surface waters of the Illinois River. We calculated unadjusted summary statistics of mean, median, and standard deviation (Table 15). The mean and median concentration of total phosphate as P exceeded 0.100 mg/l at nearly all stations except USGS 07197000 where both the mean and median were below 0.100 mg/l, and USGS 07194800 where the median value was 0.080 mg/l. There was a general decrease in median concentration of total phosphorus (in mg/l as P) as the river flowed from SR-1 to SR-5 (Table 16). This decrease tested significant at the 95% confidence level at SR-1 vs SR-2 and SR-4 vs SR-5 comparisons. The decrease between SR-3 vs SR-4 was tested significant at the 90% confidence level by the Wilcoxon signed rank test (Table 16). In general, the concentration was highest at the upper reaches of the river and in the tributaries, Osage Creek and Sager Creek.

We used a median analysis program to compare the monthly total phosphorus (as P) concentration from the upper station to the lower station using a Wilcoxon signed rank (paired test). This comparison is illustrated by comparison of the median total phosphorus (as P) concentration at USGS 07194800 versus the median concentration at USGS 07195400 (Fig. 32). This type of analysis was performed on all combinations of the upstream versus downstream stations along the mainstem of the Illinois River (Table 16, Appendix C).

There was a significant increase in median concentration of total phosphorus (as P) when comparing the upstream station USGS 07194800, near Savoy, Arkansas, with the downstream station USGS 07195400, near Siloam Springs, Arkansas above Lake Frances (Table 16). The overall increase in median concentration of total P was 0.185 mg/l during the period of record from 1 Sep 78 through 28 Sep 87. There was a decrease in median concentration of total phosphorus from USGS 07195400 to USGS 07195500, from just upstream of Lake Frances to just below (Table 16) (Fig. C-1, Appendix C). This decrease would indicate that Lake Frances was acting as a nutrient trap for some of the total phosphorus, but the difference was not significant at the 80% confidence level. However, there was a significant decrease in concentration of total phosphorus from USGS 07195500 to SR-1, during the period from 1 Dec 80 to 28 Sep 86 (Table 16).

Table 15. Summary statistics for Illinois River sampling stations for total phosphorus.				
Station ID	n (months)	Total Phosphorus as P (mg/l)		
		Mean	Median	SD
USGS 07194800	145	0.120	0.080	0.173
USGS 07195000	134	1.082	0.755	0.927
USGS 07195400	64	0.340	0.200	0.155
SR 0.5	14	0.313	0.295	0.100
USGS 07195500	170	0.293	0.198	0.313
SR 1	64	0.265	0.233	0.151
SR 2	66	0.225	0.192	0.176
USGS 07195860	117	1.496	0.820	1.021
USGS 07196000	127	0.188	0.172	0.090
SR 3	66	0.211	0.184	0.098
SR 4	66	0.201	0.170	0.081
SR 4.5	14	0.200	0.187	0.090
SR 5	66	0.181	0.133	0.295
USGS 07196500	127	0.130	0.100	0.133
SR 6	62	0.845	0.387	0.936
SR 6.3	11	0.154	0.118	0.074
USGS 07197000	126	0.079	0.044	0.102

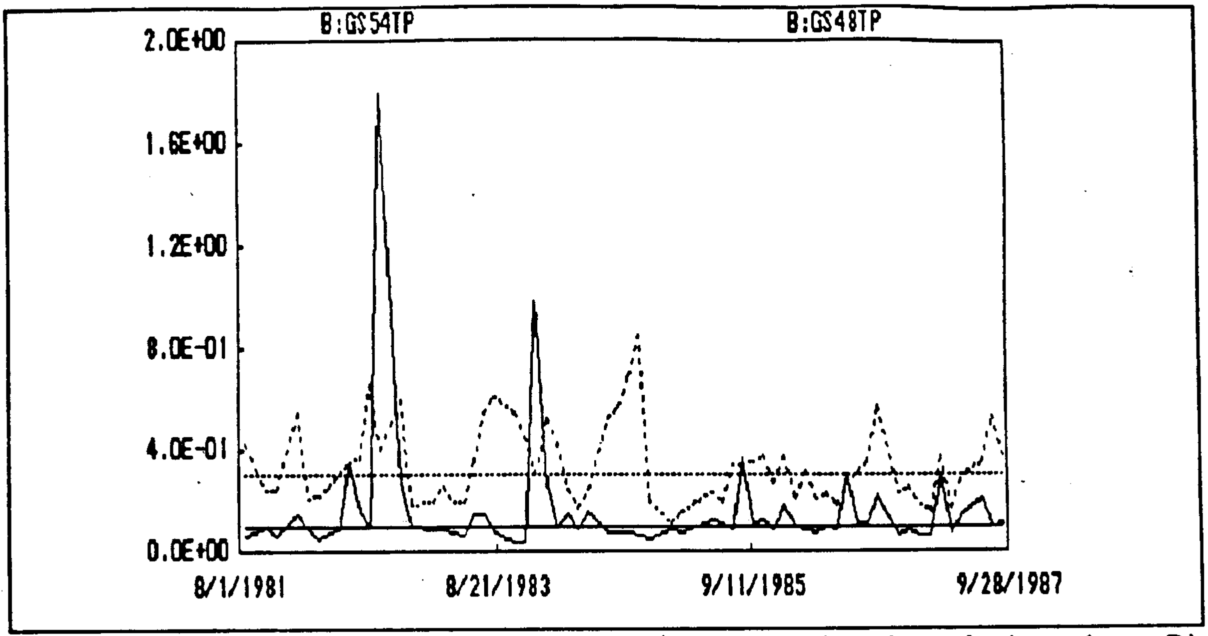

Figure 32. Comparison of median total phosphate (as P) concentration at USGS 07194800 (solid line) vs USGS 07195400 (dashed line) using the Wilcoxon signed rank test.

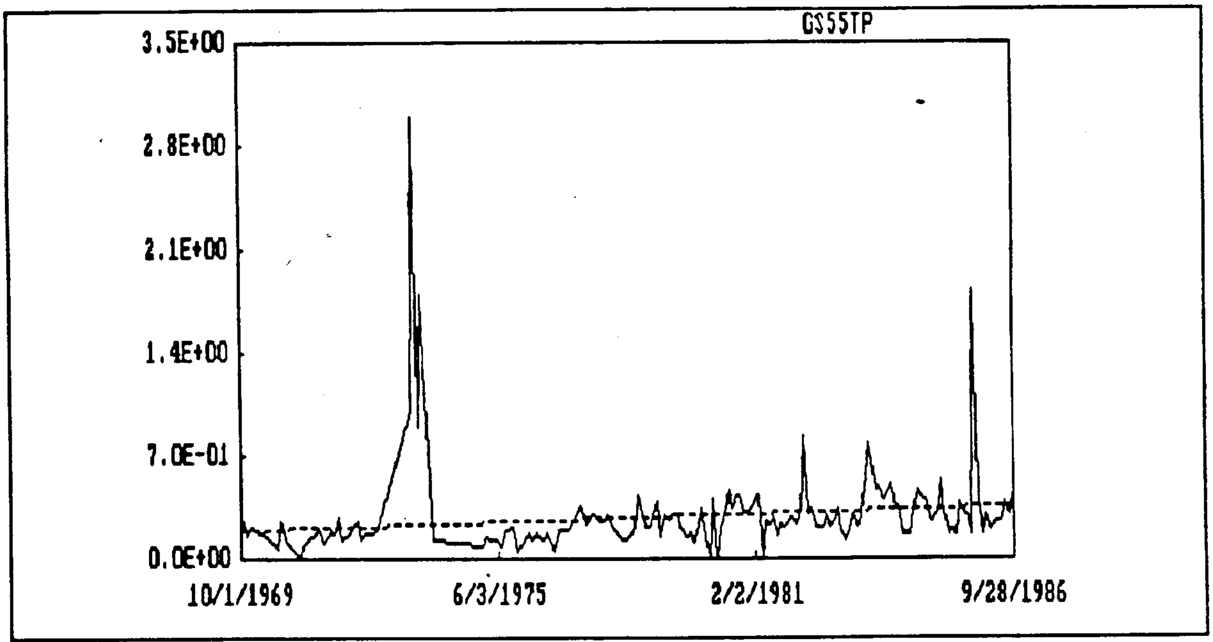

Figure 33. Total phosphorus (as P) trend at USGS 07195500 calculated from monthly averages. Slope = 0.01000 mg/l per year.

Table 16. Comparison of upstream vs downstream median concentration of total phosphorus.

Stations Compared Upstream vs Downstream	Wilcoxon Signed Rank Test Test Statistic	Seasonal Hodges-Lehmann Est. of Difference in Medians Total P (as P) (mg/l)
GS48 vs GS54	-5.838***	0.185
GS48 vs GS50	-8.933***	0.815
GS50 vs GS54	6.440***	-0.580
GS54 vs GS55	1.066	-0.018
GS55 vs SR1	2.476***	-0.041
SR1 vs SR2	4.267***	-0.042
SR2 vs SR3	1.147	-0.010
GS586 vs GS60	8.325***	-1.360
GS60 vs SR3	1.663**	-0.016
SR3 vs SR4	2.083**	-0.009
SR4 vs SR5	4.545***	-0.047
SR5 vs SR6	-6.066***	0.315

* = significant at 80% confidence level
** = significant at 90% confidence level
*** = significant at 95% confidence level

We also performed trend analyses of the total phosphorus data to aid in determining temporal changes during the period of sample collection. The data was adjusted for seasonal effects, and then Kendall's Tau and the Seasonal Kendall Tests were applied. Kendall Tau test results (Table 17) indicated 11 of the 17 stations showed increases in concentration over the period of record, significant at the 80% confidence level or greater. Seasonal Kendall test results (Table 17) indicated increasing concentrations over time at nine of the 17 stations, significant at the 80% confidence level or greater. Monthly averages were used to calculate all statistics. The Kendall Tau test, a nonparametric test based on ranks, was performed on deseasonalized data. The Seasonal Kendall test compares data from comparable seasons or months among years and accounts for seasonality internally. The Kendall Tau and Seasonal Kendall procedures test if the data values at the beginning of the data set are significantly higher or lower than the data values collected at later dates. The Seasonal Kendall Sen Slope Estimate is a nonparametric estimate of rate of change over time.

The USGS stations in Oklahoma, USGS 07195500, 07196000, 07196500, and 07197000, all showed increases in total phosphorus concentration over time significant at the 95% confidence level. Figure 34 shows graphically the time series of monthly average total phosphorus concentration at USGS 07195500 with the Seasonal Kendall Sen Slope Estimate as an example of the observed rate increase over time. The sampling station on Flint Creek above the confluence with the Illinois River (USGS 07196000) also exhibited a significant (95% CL) increase for the period of record (Table 17). The stations immediately below Lake Frances (SR-1) and downstream for a distance of several miles (SR-2 to SR-4) exhibited increases in concentration during the period of record which were not significant at the 80% confidence level (Table 17). The scenic river sampling stations just upstream from Tahlequah (SR-4.5, and SR-5) exhibited significant (95% CL) increases during the period of record as did the monitoring station just below Tahlequah, SR-6 (Table 17). Appendix B contains graphs of monthly average total phosphorus time series at all sampling stations with slope estimates included.

Table 17. Trend Tests, Total Phosphorus			
Station	Kendall Tau Test Statistic	Seasonal Kendall Test Statistic	Seasonal Kendall Sen Slope Estimate (mg/l/yr)
USGS 07194800	1.010	1.982***	0.00250
USGS 07195000	1.639*	1.810**	0.02250
USGS 07195400	-1.343*	-2.024***	-0.01333
SR 0.5	2.977***	0.707	0.13415
USGS 07195500	5.223***	5.955***	0.01000
SR 1	-1.089	-0.950	-0.00800
SR 2	-0.509	-0.794	-0.00432
USGS 07195860	3.216***	3.112***	0.07889
USGS 07196000	6.025***	5.810***	0.01143
SR 3	0.836	0.976	0.00850
SR 4	0.614	0.612	0.00409
SR 4.5	2.977***	0.707	0.06957
SR 5	2.048***	1.405*	0.00940
USGS 07196500	5.677***	5.589***	0.01257
SR 6	3.013***	2.389***	0.10400
SR 6.3	1.873**	0.000	0.00139
USGS 07197000	3.918***	2.936***	0.00540

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

Based upon summary statistics, median analyses, and trend analyses, the concentration of total phosphorus (as P) was highest at stations in the upper portion of the drainage basin. The concentration gradually decreased longitudinally from below Lake Frances (SR-1) to above Tahlequah (SR-5). The concentration increased significantly below Tahlequah STP (SR-6). The overall temporal trend at most sampling stations was an increase in concentration over the period of record.

Orthophosphate

In general, the number of samples analyzed for orthophosphate, as mg/l P, was less than the total phosphate data base. The only stations with a period of record longer than 14 months were the USGS stations in Arkansas (Table 18). The mean and the median concentration exceeded 0.1 mg/l from just below Lake Frances (USGS 07195500) to river mile 82.3 (SR 4). Concentration decreased below 0.1 mg/l until just below the Tahlequah STP outfall, where the mean and median concentration again exceeded 0.1 mg/l (SR 6).

Table 18. Summary statistics for Illinois River sampling stations for orthophosphate.

Station ID	n (months)	Orthophosphate as P (mg/l)		
		mean	median	SD
USGS 07194800	84	0.100	0.040	0.237
USGS 07195000	65	0.851	0.607	0.495
USGS 07195400	66	0.272	0.150	0.146
SR 0.5	14	0.209	0.181	0.082
USGS 07195500	14	0.207	0.162	0.105
SR 1	10	0.143	0.125	0.065
SR 2	14	0.128	0.114	0.031
USGS 07195860	46	1.417	0.690	0.739
USGS 07196000	14	0.153	0.142	0.066
SR 3	14	0.126	0.125	0.037
SR 4	14	0.124	0.110	0.048
SR 4.5	14	0.123	0.096	0.068
SR 5	14	0.078	0.075	0.047
USGS 07196500	14	0.082	0.071	0.044
SR 6	8	1.515	0.286	1.503
SR 6.3	11	0.101	0.081	0.050
USGS 07197000	14	0.030	0.022	0.031

Based upon the mean concentration of orthophosphate during the period of record, there appeared to be a considerable influx between USGS 07194800 and USGS 07195400 (Table 18). The increase was significant at a 95% CL when tested with the Wilcoxon Signed

Rank test which compared median values over corresponding time periods (Table 19). There was a gradual decrease in concentration of orthophosphate from USGS 07195400 to the station just below Lake Frances (USGS 07195500), indicating some nutrient removal in the Lake.

The orthophosphate concentration was analyzed with the Kendall Tau and the Seasonal Kendall tests to determine long term trends. Ten of the 17 sampling stations showed a trend of increasing concentration of orthophosphate over the period of record using the Kendall Tau Test. Only one of the 17 stations showed significant increases using the Seasonal Kendall Test (USGS 07194800) (Table 20). The sampling station in Lake Frances exhibited the highest rate of increase of 0.205 mg/l of orthophosphate (as P) per year. There was also a significant (95% CL) increase in orthophosphate at SR-3 of 0.072 mg/l (P) per year. Most of the other downstream stations, i.e., from SR-4 to USGS 07196500 showed a temporal increase in orthophosphate (as P) during the period of record. USGS 0719500, a tributary to Illinois River above Lake Frances, and USGS 07195860, a tributary to Flint Creek, showed significant decreases. The longer period of record at the Arkansas USGS stations (07194800, 07195000, 07195400, and 071958600) allows for a greater amount of confidence in results of trend tests at those stations.

The overall trend in orthophosphate (as P) concentration along the main stem of the Illinois River was an increase during the period of record. However, this overall result may be somewhat anomalous due to the short period of record at all Oklahoma sampling stations. The two stations located on tributaries (USGS 0719500 & 07195860) showed an opposite trend of decreasing concentration. The mean concentration of orthophosphate (as P) was highest at the stations in the tributaries and upper reaches of the river. The mean concentration showed a gradual decline longitudinally from the upstream to downstream stations. Time series graphs of monthly average orthophosphate with slope estimates are in Appendix D. Median orthophosphate concentration comparison graphs of upstream versus downstream stations are in Appendix E.

Table 19. Comparison of upstream vs downstream median concentration of orthophosphate.

Stations Compared Upstream vs Downstream	Wilcoxon Signed Rank Test Test Statistic	Seasonal Hodges-Lehmann Est. of Difference in Medians Ortho P (as P) (mg/l)
GS48 vs GS50	-5.893***	0.660
GS48 vs GS54	-5.629***	0.160
GS54 vs GS55	1.956**	-0.080
GS55 vs SR1	2.090***	-0.043
SR1 vs SR2	0.968	-0.018
GS586 vs GS60	3.059***	-0.930
GS60 vs SR3	1.538*	-0.024
SR2 vs SR3	0.785	-0.009
SR3 vs SR4	2.354***	-0.011
SR4 vs SR4.5	0.471	-0.006
SR4.5 vs SR5	2.731***	-0.021
SR5 vs GS65	-0.941	0.000
GS65 vs SR6	-2.380***	0.978
SR6 vs SR6.3	2.197***	-1.625

* = significant at 80% confidence level
** = significant at 90% confidence level
*** = significant at 95% confidence level

Table 20. Trend Tests for Orthophosphate			
Station	Kendall Tau Test Statistic	Seasonal Kendall Test Statistic	Seasonal Kendall Sen Slope Estimate (mg/l/yr)
USGS 07194800	1.236	2.900***	0.00500
USGS 07195000	-3.057***	-2.692***	-0.06500
USGS 07195400	-0.210	-0.597	-0.00250
SR 0.5	2.977***	0.707	0.20512
USGS 07195500	2.977***	0.707	0.16317
SR 1	1.044	0.000	0.00000
SR 2	0.069	0.000	0.00570
USGS 07195860	-3.446***	-2.631***	-0.18125
USGS 07196000	2.977***	0.707	0.04840
SR 3	2.977***	0.707	0.07175
SR 4	2.977***	0.707	0.06533
SR 4.5	2.977***	0.707	0.07965
SR 5	2.977***	0.707	0.08229
USGS 07196500	2.977***	0.707	0.07175
SR 6	0.873	0.000	0.00000
SR 6.3	1.873**	0.000	0.00000
USGS 07197000	2.977***	0.707	0.04731

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

Monthly averages used to calculate all statistics. The Kendall Tau Test was performed on deseasonalized data.

NITROGEN

Nitrites/Nitrates

The mean concentration of nitrite + nitrate nitrogen exceeded 1.0 mg/l at all Illinois River Basin stations, except for USGS 07197000 (Table 20). The mean concentration of nitrite + nitrate nitrogen was 4.08 mg/l at the USGS 07195000 station on Osage Creek which was the highest overall mean value. The mean concentration gradually declined from the upstream stations to the downstream stations along the main stem of the river.

Table 21. Summary statistics for nitrite/nitrate for the Illinois River sampling stations.

Station ID	N (months)	Nitrite/Nitrate (mg/l)		
		Mean	Median	SD
USGS 07194800	121	1.496	1.300	0.824
USGS 07195000	108	4.081	4.000	1>262
USGS 07195400	66	2.269	1.700	0.638
SR 0.5	14	1.843	1.625	0.749
USGS 07195500	110	1.510	1.200	0.873
SR 1	64	1.819	1.800	0.966
SR 2	66	1.673	1.400	1.491
USGS 07195860	80	2.888	2.250	1.031
USGS 07196000	98	1.291	1.100	0.679
SR 3	66	1.480	1.475	0.778
SR 4	66	1.459	1.300	0.797
SR 4.5	14	1.357	1.417	0.647
SR 5	66	1.293	1.200	0.953
USGS 07196500	96	1.052	0.800	0.718
SR 6	62	2.245	1.600	1.619
SR 6.3	10	1.266	1.200	0.550
USGS 07197000	98	0.914	0.700	0.628

Most of the sampling stations, except for USGS 07195000 on Osage Creek, SR 0.5 in Lake Frances, and USGS 07196000 on Flint Creek, exhibited a positive increase in concentration of nitrite +

nitrates over the period of record (Table 21). The highest rate of increase occurred at SR-4.5, an increase of 0.269 mg as N per year. However, the increase at SR-4.5 did not test significant due to the small number of samples. The next highest increase 0.320 mg/l as N per year (significant at 95% CL) occurred at SR 6. Thus the overall trend in nitrite + nitrate (as N) during the period of record showed a significant increase at most stations (times series graphs of monthly average nitrite + nitrate concentrations with slope estimates and median nitrite + nitrate concentration comparisons are in Appendices F and G respectively).

The highest mean concentrations of nitrite + nitrate (as N) on the Illinois River mainstem occurred in the upstream stations (USGS 07195400, SR 0.5, and SR 1) and tended to decrease at the downstream stations (Table 20). Comparison of the median concentration of the upstream station versus the adjacent downstream station by Wilcoxon Signed Rank Test indicated that a significant (95% CL) decrease occurred at 6 of the station pairs (Table 22). Another station comparison (SR4 vs SR4.5) showed a significant decrease at the 80% CL (Table 22). Only three locations showed a significant (95% CL) increase in median concentration from the upstream vs the downstream station, USGS 07194800 vs USGS 07195400, USGS 07195500 vs SR 1 and USGS 07196500 vs SR 6.

The overall pattern of nitrite + nitrate concentration in the Illinois River basin appeared to be high concentrations in the tributaries & upper reaches. The concentration tended to decrease when comparing upstream versus downstream locations, however there was generally a significant increase in concentration over time at a specific location.

Table 22. Trend Tests, Nitrite + Nitrate			
Station	Kendall Tau Test Statistic	Seasonal Kendall Test Statistic	Seasonal Kendall Sen Slope Estimate (mg/l/yr)
USGS 07194800	3.054***	2.981***	0.05000
USGS 07195000	-0.199	-0.994	-0.02500
USGS 07195400	2.005***	0.998	0.05000
SR 0.5	-0.069	0.000	-0.27200
USGS 07195500	3.175***	2.400***	0.03333
SR 1	2.943***	2.803***	0.15000
SR 2	1.611*	1.603*	0.07500
USGS 07195860	2.356***	1.845**	0.08542
USGS 07196000	0.510	0.177	0.00000
SR 3	3.764***	3.507***	0.15000
SR 4	3.232***	2.425***	0.10250
SR 4.5	0.069	0.000	0.26917
SR 5	2.519***	2.447***	0.10917
USGS 07196500	1.377*	1.082	0.01250
SR 6	3.116***	2.545***	0.32000
SR 6.3	---	---	---
USGS 07197000	0.854	-0.287	0.00000

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

Monthly averages used to calculate all statistics. The Kendall Tau Test was performed on deseasonalized data.

Table 23. Comparison of upstream vs downstream median concentration of nitrite/nitrate.

Stations Compared Upstream vs Downstream	Wilcoxon Signed Rank Test Test Statistic	Seasonal Hodges-Lehmann Est. of Difference in Medians Total NO2/NO3 (as mg/l N)
GS48 vs GS50	-8.159***	2.700
GS48 vs GS54	-5.354***	0.600
GS54 vs GS55	2.445***	-0.600
GS55 vs SR1	-0.987	0.100
SR1 vs SR2	3.683***	-0.200
SR2 vs GS60	2.854***	-0.125
GS586 vs GS60	7.097***	-1.500
GS60 vs SR3	-1.872**	0.100
SR2 vs SR3	0.357	-0.000
SR3 vs SR4	2.562***	-0.000
SR4 vs SR4.5	1.433*	-0.062
SR4 vs SR5	4.744***	-0.200
SR5 vs GS65	1.306*	0.000
GS65 vs SR6	-4.573***	0.800
SR6 vs SR6.3	NEDA	NEDA

*   = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level
NEDA = not enough data for analysis

Ammonia

The mean and median concentrations of ammonia were relatively high, for surface streams, at USGS 07194800 and SR-0.5 (in Lake Frances) (Table 23). Again, the period of record was longer at Arkansas USGS stations than the 14 months at all Oklahoma monitoring stations. The presence of significant concentrations of ammonia would generally be interpreted to indicate relatively recent introductions of animal wastes, municipal wastewaters, or other anthropogenic activities.

There was a significant (95% CL) temporal decrease in concentration of ammonia at USGS 07195400, 07195860, 07196000, and 07197000 during the period of record based on Kendall Tau Test results (Table 24)> Most confidence should be placed on trend test results at Arkansas stations since the period of record spans several years at these stations. Of these four stations, three indicated decreasing trends in concentration over the period of record significant at least the 80% confidence level. This may indicate a general improvement in method of disposing of animal wastes or reduction in municipal wastewater ammonia concentration. However, the apparent reduction could also be an anomaly of increased discharge during the last few years of data collection, i.e. greater dilution. There appeared to be no general trend in temporal concentration of ammonia over all of the sampling stations. Time series graphs of monthly average ammonia concentrations with slope estimates are in Appendix H.

The median concentration of ammonia showed a significant (95% CL) decrease from USGS 07194800 to USGS 07195400 (Table 25). There was a significant (95% CL) increase from USGS 07195400 to SR-0.5 which is within Lake Frances, possibly reflecting the severe eutrophication conditions in the lake. Comparison of most of the other stations showed a gradual decline in ammonia concentration from upstream to downstream stations, except at SR-4 vs SR-4.5, which exhibited a slight increase. This would indicate the presence of a point source input between SR-4 and SR-4.5. There was an obvious and expected significant increase below the Tahlequah STP. Graphic comparisons of median ammonia concentrations at upstream versus downstream stations are in Appendix H.

The relative concentration of ammonia at the different stations along the river was probably not significant with respect to it's contribution to eutrophication problems. However, the consistent presence of ammonia at some sampling stations in the upper end of the basin probably reflect input from municipal STP's or animal wastes. The slight increase between SR-4 and SR-4.5 indicates another potential point source of contamination.

Table 24. Summary statistics for ammonia for the Illinois River sampling stations.

Station ID	N (Months)	Ammonia (mg/l)		
		Mean	Median	SD
USGS 07194800	124	0.077	0.040	0.120
USGS 07195000	117	0.221	0.080	0.442
USGS 07195400	71	0.052	0.015	0.086
SR 0.5	14	0.095	0.096	0.054
USGS 07195500	14	0.166	0.156	0.117
SR 1	4	0.292	0.063	0.443
SR 2	13	0.084	0.050	0.051
USGS 07195860	90	0.642	0.120	0.945
USGS 07196000	14	0.085	0.052	0.108
SR 3	14	0.083	0.053	0.075
SR 4	14	0.068	0.051	0.049
SR 4.5	14	0.073	0.064	0.053
SR 5	14	0.069	0.055	0.050
USGS 07196500	14	0.057	0.032	0.043
SR 6	---	---	---	---
SR 6.3	11	0.053	0.041	0.042
USGS 07197000	14	0.067	0.054	0.041

Table 25. Trend tests for ammonia

Station	Kendall Tau Test Statistic	Seasonal Kendall Test Statistic	Seasonal Kendall Sen Slope Estimate (mg/l/yr)
USGS 07194800	-1.538*	-1.778**	-0.00155
USGS 07195000	1.267	1.155	0.00366
USGS 07195400	-2.866***	-2.813***	-0.00250
SR 0.5	-2.977***	-0.707	-0.02205
USGS 07195500	-2.977***	-0.707	-0.06412
SR 1	---	---	---
SR 2	-2.161***	0.000	0.00000
USGS 07195860	-2.328***	-2.311***	-0.02500
USGS 07196000	-2.977***	-0.707	-0.05703
SR 3	-0.069	0.000	-0.00907
SR 4	0.069	0.000	0.03675
SR 4.5	-0.069	0.000	-0.01498
SR 5	-0.069	0.000	-0.00387
USGS 07196500	-0.069	0.000	-0.02046
SR 6	---	---	---
SR 6.3	1.873**	0.000	0.00000
USGS 07197000	-2.977***	-0.707	-0.07345

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

Monthly averages used to calculate all statistics. The Kendall Tau Test was performed on deseasonalized data.

Table 26. Comparison of upstream vs downstream median concentration of ammonia.

Stations Compared Upstream vs Downstream	Wilcoxon Signed Rank Test Test Statistic	Seasonal Hodges-Lehmann Est. of Difference in Medians Ammonia (as N) (mg/l)
GS48 vs GS50	-4.758***	0.030
GS48 vs GS54	4.195***	-0.020
GS54 vs SR05	-2.746***	0.068
GS54 vs GS55	-2.981***	0.137
SR05 vs GS55	-2.275***	0.064
GS55 vs GS60	2.132***	-0.095
SR1 vs SR2	-0.447	0.000
SR2 vs SR3	1.021	-0.005
SR3 vs SR4	0.663	0.000
SR4 vs SR45	0.000	-0.005
SR45 vs SR5	0.153	0.000
SR5 vs GS65	1.244	0.000
GS65 vs SR63	0.801	-0.011

* = significant at the 80% confidence level
** = significant at the 90% confidence level
*** = significant at the 95% confidence level

ALGAE

The analysis is divided into three segments: Lake Frances, Illinois River phytoplankton and Illinois River periphyton. The isolation of Lake Frances from the general discussion of the phytoplankton is a recognition that this reservoir represent a distinct ecosystem which is truly reservoir-like.

Lake Frances Phytoplankton

The reduction of flow and the extended retention time result in the replacement of riverine planktors and tychoplantors of the upper Illinois River with true lake/reservoir planktonic algal species. These species are adapted to less turbulent water and use various mechanisms to maintain buoyancy. As water velocity is reduced, many of the stream plankters settle from the water column and are replaced by better adapted species.

Four papers contain adequate information to contribute some insight into the character of Lake Frances. Each of these reports use different methods (see Objective 2 report) and have divergent goals. Chronologically, these papers included mid-June vertical sampling by the Oklahoma State Department of Health (OSDH 1976) composite sampling during three seasons by EPA under the 701 program, 13 monthly samples from three sites by Threlkeld (1982), and three samples from three sites by EPA in 1985 (Gakstatter and Katko 1985). In combination, these reports provide a generalized qualitative view of the phytoplankton in the reservoir.

The specific quantitative values must be viewed with caution and should be used for comparative purposes for observed variation within the study because of differences in quality of enumeration methods and techniques. The analytical techniques used for the EPA 701 program and the later EPA study (Gakstatter and Katko, 1986) used the Neubauer Chamber and Utermohl methods, respectively. The latter method provides the more reliable data. The protocol used by OSDH is unknown, while the method used by Threlkeld (1982) lacks precision and accuracy.

It should by noted that as the accuracy and precision of the enumeration method; therefore, the reliability of the data, increases the known abundance of algae decreases. The 1986 EPA data reports a maximum of ca. 380,000 organisms/liter at station LF-2E (Figures 34 and 35) during August, while Threlkeld (1982) reported means of over 40,000,000 and 80,000,000 org/l (Figures 36 and 37) during the same season. Similarly, a comparison of April and June date from EPA (1978) (Figures 38 and 39) and from Threlkeld (1982) reveal striking differences. April EPA reports ca. 2,000,000 org/l, while Threlkeld reports 34,000,000 org/l and in June EPA records 300,000 org/l, while Threlkeld found ca. 11,000,000 org/l. Lesser differences are noted in comparing October values. Approximately 4,700,00 and 8,000,000 (1981) or

11,000,000 org/l (1982) are reported by EPA and Threlkeld, respectively.

Threlkeld's 1982 report includes the only seasonal phytoplankton data from Lake Frances (Figures 36 and 37). These data show a general bimodal annual distribution pattern. In general, the phytoplankton have minimal population during the late fall/winter months with a spring maximum in April and May. This is followed by a population crash in early summer with a gradual recovery during midsummer. This recovery leads to sub-maximum in late summer, August, followed by a decrease in September. The seasonal population dynamics of Lake Frances should be included when comparing with data from other studies and estimating long-term trends.

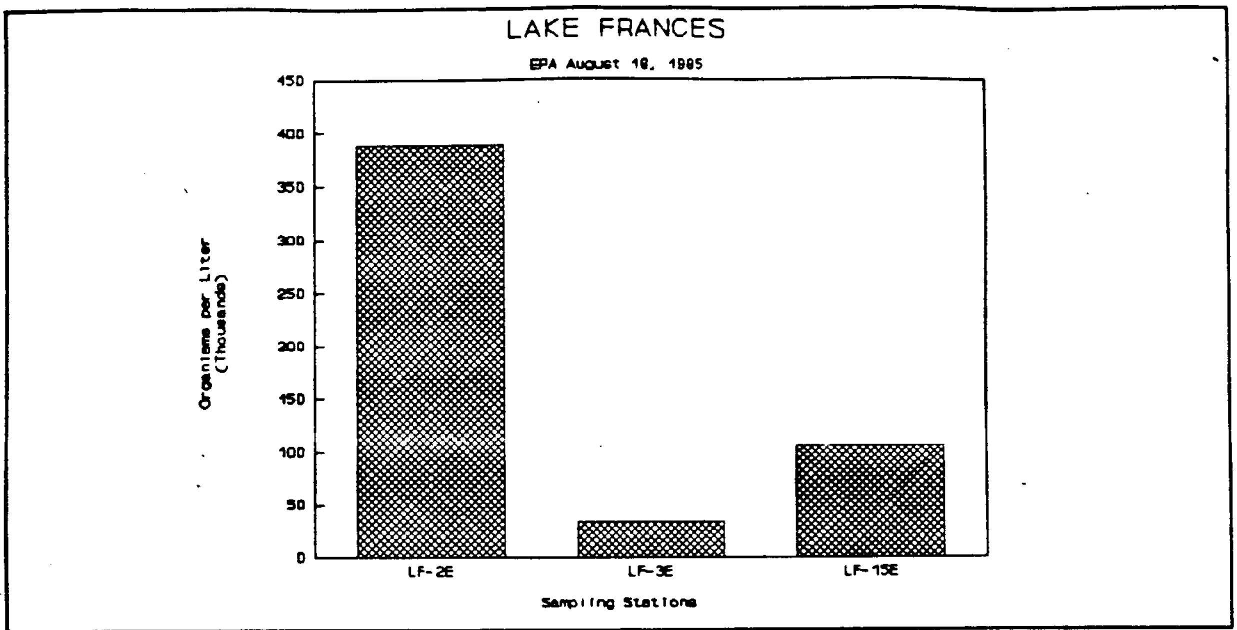

Figure 34. Abundance of phytoplankton from three stations in Lake Frances on August 18, 1985 (EPA, 1985).

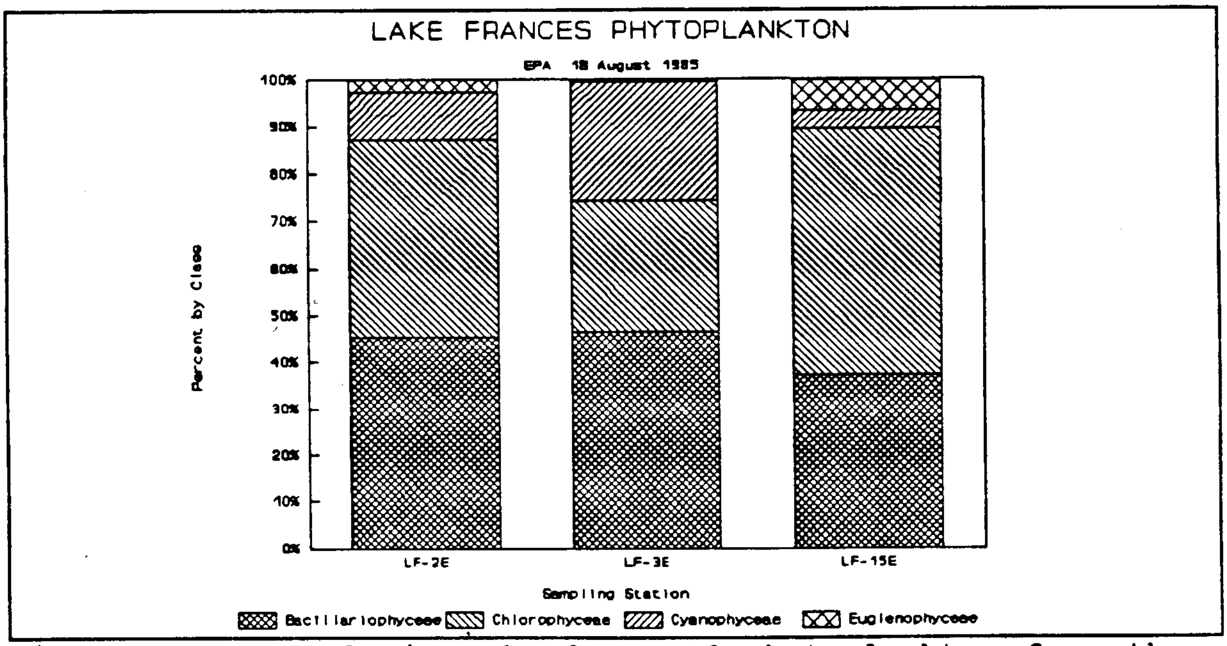

Figure 35. Relative abundance of phytoplankton from three stations in Lake Frances on August 18, 1985 (EPA, 1985).

FISH

Species Richness

Dr. George Moore, a prominent ichthyologist at Oklahoma State University, made many collections from the Illinois River dating back to the 1920's. He stated that the river is one of the richest in the United States in number of species (Moore and Paden 1950). He recognized the excellent location between the Gulf of Mexico and the Great Lakes. Springs in Arkansas and Oklahoma provide a reliable source of water and enabled the establishment of fish from the Ozark Uplands, while plains fauna reached the river from the Arkansas River. Cloutman and Olmsted (1970) was impressed with the richness of species in the headwaters of the river. They found many species that are widely distributed in the eastern United States as well as several species that have an Ozarkian distribution. However, several prairie and lowland forms that occur downstream were lacking in the head waters. Smith (1985) made extensive collections in the middle reaches of the river in 1974, 1981, and 1984 and found an abundant fish assemblage in terms of numbers, weight, and variety of species.

Many studies of fish species have been conducted in various parts of the river. In an extensive study in the headwaters, Cloutman and Olmstead (1970) collected 66 species of fish in 122 collections at 78 sites from 1970 to 1974. Moire and Paden (1950) collected 92 species of fish in the Illinois River from Lake Francis to the mouth in 1946. Other studies in this area yielded 75 species in 1952 (Jenkins et al. 1952), 67 species in 1976-77 (OSDH 1978), and 69 species in surveys in 1974, 1981, and 1982 (Smith 1985). The Oklahoma State Department of Health (1976) stated that 108 different species of fish had been collected in the Illinois River to 1976. Smith reported that 117 species have apparently been found in the Illinois River at one time or another.

We assembled a list of all species of fish collected in the Illinois River and its tributaries in the 43 papers pertaining to fish that we obtained in Objective I. Fifteen species were eliminated from the list because they were temporary residents (e.g. one tropical fish was collected and assumed to have been dumped, the muskellunge was stocked in Tenkiller Lake in 1967 but none was ever collected by anglers or in subsequent sampling) or were synonyms of other species on the list. After these deletions, the number of species collected in the Illinois River and its tributaries from 1891 to the present total 132.

Longitudinal Changes

Cloutman and Olmsted (1976) described ecological associations and temporal changes in the headwaters of the Illinois River. They noted that species richness of fishes in Washington County tend to increase from the headwaters to downstream areas, primarily because of variation in stream gradient and size which determines volume, rate of flow, pool to riffle ratios, and amount of silt deposition. Stream gradient is highest in the headwaters. They classified seven major types of aquatic habitats in Washington County.

The longitudinal variation of total number of species, species diversity, intolerant species, rare species, and sport fishes at the different sampling stations is given in Figures 53 through 57. The data were collected on 13 through 16 June 1976 by the Oklahoma Department of Health (1985). The tabular data are given in Table 6 of the fish section of Objective II. The largest variation existed at the station near Watts OK, Station 1955. This station had a considerably larger number of species collected, value of species diversity, sport fishes, and rare species. At most sampling stations, total number of species collected ranged from fifteen to twenty, while species diversity ranged between 1.0 and 2.0. Of the total number of species collected, generally eight to eleven were intolerant species and four to eight were sport fish. Rare species were generally collected in greater numbers at the upstream station than at the downstream station. The greatest number of rare species were collected near the confluence with Flint Creek, Station 1958.

Temporal Changes

As described in the Fish Section of Objective II, Cloutman and Olmsted felt that the Indians who inhabited Washington County since 9500 B.C. and the early white settlers had little effect on the fish populations. However, by 1940 cutting of many forested areas in the watershed and the increase in agriculture may have increased drying of the soil and flooding, and decreased the quality of fishing. After 1940, urbanization increased and the number of farms decreased. However, the number of livestock and poultry increased and organic pollution started to increase. Cloutman and Olmsted felt that the abundance of the golden shiner, redfin shiner, mosquito fish, and bluegill and the absence or rarity of these species in earlier collections by Meek suggest that there has been an increase in turbidity since 1940. The bigeye chub has probably decreased in abundance due to siltation or turbidity. Cloutman and Olmsted felt that the most significant impact of man on fish in Washington County was the impoundment of several streams. Dams have blocked migration routes by such fish as the American eel. Most of the impoundments are small in size. Man has also introduced exotic fish species.

Jim Smith, Oklahoma Department of Wildlife Conservation (ODWC), provided a thorough analysis of temporal changes in fish species in the Illinois River from Lake Francis Dam to Tenkiller Lake (Smith 1982). His analysis was based on samples taken by ODWC personnel in 1974, 1981, and 1982. Samples were taken by electrofishing, seining, and riffle disruption. They collected 69 species in the three surveys. The greatest number of species were collected in the lower one-third of the study reach, while the fewest species were collected in the upper section which remains turbid from Lake Frances almost to Flint Creek. In the 1974 study, the OSDH measured water quality of the Illinois River and concluded that the discharge from Lake Frances contributed 50 to 70% of the total nutrient concentration to the river in Oklahoma.

Smith reported that of the 117 species reported in the Illinois River and its tributaries, forty are no longer expected in the river and its tributaries between Lake Frances Dam and Tenkiller Lake. He stated that six of these are expected from the Arkansas section, five are limited to Tenkiller Lake, fourteen should occur below Tenkiller Dam, and fifteen are presumed to have disappeared from the drainage basin. The fifteen presumed no longer present are the Mexican tetra, muskellunge, silvery minnow, speckled chub, silver chub, ghost shiner, ribbon shiner, sand shiner, mimic shiner, mountain madtom, tadpole madtom, neosho madtom, johnny darter, channel darter, and river darter. The Mexican tetra was probably a pet discarded and the muskellunge was stocked into Tenkiller Lake in 1967 but never collected by anglers or ODWC personnel. The remaining thirteen were always classified as rare.

The ODWC sampling also enabled calculation of abundance based on frequency of occurrence. Twenty-five of the 77 species within the study reach were more abundant in 1982 than in 1974, while only 14 were less abundant in 1982. In 1982, sixteen of the expected 77 species were classified as very abundant and only six of those were very abundant in 1974. Twenty-four of the 77 species were listed as common in 1982, while only fourteen were common in 1974.

Catch rates as determined by electrofishing by boat increased from 1974 to 1982 for largemouth, spotted, smallmouth, white rock, and striped bass; channel catfish; bluegill; longear, orange, and green sunfish; warmouth; carp; drum; smallmouth and bigmouth buffalo; river and highfin carpsucker; yellow and black bullhead; northern hogsucker; spotted sucker; river, black, golden, and shorthead redhorse; flathead catfish; longnose gar; and gizzard shad. Decreases were recorded only for white crappie, black crappie, and redear sunfish.

Smith also compared his data with that of Jenkins (1952). He stated that there have been changes in species composition and distribution, but that these changes have been gradual. Recreational use of the river has increased dramatically and some pollution problems exist. However, the construction of the dam and formation of Tenkiller Lake has resulted in more changes in species composition, abundance, and distribution of fish than any of the other factors. Smith was concerned about the decline in numbers of smallmouth bass and perhaps the lack of quality size fish, a situation also noted by Jenkins. The Missouri Department of Conservation also reported the decrease in quality of smallmouth bass fishing in many Ozark streams in the 1950's and felt that a major contributing factor was the increase in fishing on these streams.

Trend analyses of the total number of species, species diversity, intolerant species, sport species, and rare fish collected are shown in Figures 57 through 61. The data were collected at Tahlequah station 1965, from 1976 to 1986 by the Oklahoma State Department of Health. A table of temporal variation is given in Table 5 of Objective II. All of these variables except the number of rare species collected had a positive slope suggesting a general improvement in the diversity of the fish assemblage. However, it does not indicate changes in the biomass or quality of the fish assemblage.

We compared the relative abundance of the different feeding types of fish before and after 1970 to determine if changes in water quality were accompanied by increases or decreases in fish eating particular types of food. An increase in nutrients might accelerate algal production and density and in crease the variety of grazers. The Atlas of North American Fishes (Lee et al. 1980); the Fishes of Missouri (Pflieger 1975); Freshwater Fishes of Canada (Scott and Crossman 1973); and Fishes of Arkansas (Robinson and Buchanan, 1988) were used to determine feeding type. However, there was little change in the number of species at the different feeding types (Table 28). Over 50% of the species were either invertivores or bottom feeders both before and after 1970. The number of species of grazers did not change over time. Although the total number of species collected increased from 108 before 1970 to 116 after 1970, this difference probably resulted from the greater number of samples taken after 1970.

Summary

A large number of collections of fish have been taken from the Illinois River and its tributaries. The river contains a diverse assemblage of fish. We listed 132 species collected in the 43 studies we examined. The variety of gear and methods used to collect fish in these stations preclude quantitative comparison among studies. Based on qualitative information, it appears that there is still a diverse and abundant assemblage of fish in the Illinois River. However, there was a trend toward an increase in the number of species, species diversity, intolerant species, and sport species between 1976 to 1981 in the river near Tahlequah. In order to evaluate subtle changes that may have occurred as water clarity changed, it would be necessary to have accompanying information on abundance and biomass over time. This information is limited and thus conclusions are based largely on the presence or absence of species.

Table 27. Species, feeding type[1] and time collected[2] and studies in which the species were collected[3] of fish in the Illinois River and its tributaries

FISH

1: I - Invertivores
B - Bottom feeders
IP - Invertivores - Piscivores
G - Grazers
P - Piscivores
PI - Piscivores - Invertivores
? - Unknown

2: * - Collected prior to 1970
** - Collected after 1970
*** - Collected before and after 1970

3: File number (Reference were given by file number in objective)

Alosa alabamae - Alabama Shad (I) ** (14,58,61)
Alosa chrysochloris - Skipjack herring (P) ***(14,15,17,58,61,64)
Ambloplites rupestris - Rock bass (I) *** (3,8,14,17,20,23,32,58,61,62,64,78,129,130)
Amblyopsis rosae - Ozark cavefish (IP) ** (14,58,61)
Anguilla rostrata - American eel (B) *** (14,17,58,61,129)
Aplodinotus grunniens - Freshwater drum (B) *** (3,17,64,129,135)
Campostoma anomalum - Stoneroller (G) *** (8,11,12,14,15,17,20,21,32,58,62,64,78,112,120,128,129,130,131)
Campostoma oligolepis - Largescale stoneroller (G) ** (14,32,58,128,129)
Carassius auratus - Goldfish (G) *** (14,17,58,61,78,129)
Carpiodes carpio - River carpsucker (B) *** (3,14,15,17,23,58,61,62,64,135)
Carpiodes cyprinus - Quillback (B) ** (129)
Carpiodes velifer - Highfin carpsucker (B) *** (3,14,15,58,64,129,135)
Catostomus commersoni - White sucker (B) *** (14,15,17,18,20,32,58,78,129,130)
Cottus carolinae - Banded sculpin (IP) *** (8,12,14,17,20,32,58,61,78,120)
Ctenopharyngodon idella - Grass carp (G) ** (14,58,61,129)
Cycleptus elongatus - Blue sucker (I) ** (14,58)
Cyprinus carpio - Common Carp (B) *** (3,14,15,17,58,62,64,78,129,135)
Dorosoma cepedianum - Gizzard Shad (G) *** (3,8,14,15,17,23,58,61,62,64,78,129,135)
Dorosoma petenense - Threadfin shad (G) ** (14,129)
Esox lucius - Northern Pike (P) ** (129)

Etheostoma blennioides - Greenside darter (I) *** (8,14,17,18,58, 61,78,129)
Etheostoma caeruleum - Rainbow darter (IP) ** (129)
Etheostoma cragini - Arkansas darter (G) **
Etheostoma euzonum - Arkansas saddled darter (I) ** (129)
Etheostoma flabellare - Fantail darter (I) *** (8,11,12,14,17,18, 20,21,32,58,61,78, 120,129,130,132)
Etheostoma juliae - Yoke darter (I) ** (129)
Etheostoma microperca - Least darter (I) *** (14,17,58,61,78,129)
Etheostoma nigrum - Johnny darter (I) ** (14)
Etheostoma punctulatum - Stippled darter (I) *** (8,12,14,17,20, 32,58,61,78,129, 130,132,149)
Etheostoma spectabile - Orangethroat darter (I) *** (8,11,12,14, 17,18,20,21, 32,58,61,78, 120,129,130, 132,149)
Etheostoma stigmaeum - Speckled darter (I) ** (14,58,61,78,129)
Etheostoma whipplei - Redfin darter (I) *** (14,17,18,58,61,78, 129)
Etheostoma zonale - Banded darter (I) *** (8,12,14,17,18,32,58, 61,78,129,130)
Fundulus catenatus - Northern studfish (B) ** (8,14,20,32,58,78, 128,120,130)
Fundulus notatus - Blackstripe topminnow (I) *** (8,14,15,17,58, 64)
Fundulus olivaceus - Blackspotted topminnow (I) *** (8,11,14,15, 20,21,58,64, 78,120,130)
Fundulus sciadicus - Plains topminnow (?) *** (14,17)
Gambusia affinis - Mosquito fish (I) *** (8,11,12,14,17,20,21,32, 58,61,62,64,78,112,129, 130,132)
Hiodon alosoides - Goldeye (IP) *** (14,15,58,61,64)
Hiodon tergisus - Mooneye (IP) ** (129)
Hybognathus nuchalis - Central silvery minnow (G) *** (14,15,58, 61)
Hybognathus placitus - Plains minnow (G) *** (14,58,61,64)
Hybopsis aestivalis - Speckled chub (B) *** (14,15,58,61,64)
Hybopsis amblops - Bigeye chub (B) *** (8,12,14,15,17,18,32,58, 61,64,78,129)
Hybopsis dissimilis - Streamline chub (B) *** (15,17,18,129)
Hybopsis punctata - Gravel chub (B) *** (12,14,58,61,78,129)
Hybopsis storeriana - Silver Chub (B) *** (14,15,17,58,61,64)
Hypentelium nigricans - Northern hog sucker (B) *** (15,17,20, 64,129,130)
Ichthyomyzon castaneus - Chestnut lamprey (P) *** (8,14,15,58,61, 64,78,129)
Ichthyomyzon gagei - Southern brook lamprey (B) *** (14,15,58,61, 129)

Ictalurus furcatus - Blue catfish (PI) ** (14,58)
Ictalurus melas - Black bullhead (I) ** (3,8,11,12,14,15,17,23, 58,64,78,129,130,135)
Ictalurus natalis - Yellow bullhead (IP) ** (3,8,11,12,14,15,17, 58,64,78,129,130)
Ictalurus punctatus - Channel catfish (IP) ** (3,8,14,15,17,23, 58,62,64,78,111, 112,129,135)
Ictiobus bubalus - Smallmouth buffalo (B) *** (3,14,15,17,58,64, 78,129)
Ictiobus cyprinellus - Bigmouth buffalo (B) *** (3,14,15,17,58, 64,129)
Ictiobus niger - Black buffalo (I) *** (3,15,17,23,58,64,135)
Labidesthes sicculus - Brook silverside (I) *** (8,14,17,32,58, 61,62,64,78,129)
Lepisosteus osseus - Longnose gar (P) *** (8,14,15,17,58,61,64, 78,112,129)
Lepiosteus oculatus - Spotted gar (IP) ** (14,17,58,61)
Lepisosteus platostomus - Shortnose gar (IP) ** (14,58,61)
Lepomis cyanellus - Green sunfish (IP) *** (3,8,11,12,14,17,20, 23,21,32,58,61,62,64, 78,120,129,130)
Lepomis gulosus - Warmouth (P) *** (3,8,14,17,23,58,61,64,78,129, 130)
Lepomis humilis - Orangespotted sunfish (IP) *** (14,17,58,61,62, 64,78,129)
Lepomis macrochirus - Bluegill (IP) *** (8,11,12,14,17,20,21,23, 32,58,61,62,64,78,129, 135)
Lepomis megalotis - Longear sunfish (IP) *** (3,8,11,12,14,17,20, 21,23,32,58,61,62, 64,78,120,129,130, 135)
Lepomis microlophus - Redear sunfish (I) *** (3,8,14,23,32,58,61, 64,78,129,130)
Menidia audens - Tidewater Silverside (I) ** (58,61)
Micropterus dolomieui - Smallmouth bass (IP) * (3,8,11,12,14,17, 20,21,23,32,34,58, 61,64,78,129,130, 132,135)
Micropterus punctulatus - Spotted bass (IP) * (3,8,11,12,14,17, 21,23,58,61,64,78, 129,135)
Micropterus salmoides - Largemouth bass (I) * (3,8,14,17,23,32, 34,58,61,64,78,120, 129,135)
Minytrema melanops - Spotted sucker (B) *** (3,11,14,15,17,21,23, 34,58,62,64,78,112, 129,130)
Morone chrysops - White bass (PI) *** (3,14,17,58,61,129,135)
Morone saxatilis - Striped bass (P) *** (14,18,58,61,129)
Moxostoma carinatum - River redhorse (I) * (3,14,58,78,129)

Moxostoma duquesnei - Black redhorse (I) * (3,14,15,17,58,64,78, 129,130)

Moxostoma erythrurum - Golden redhorse (B) * (3,11,12,14,15,17, 21,23,32,58,62,64, 78,129,130,135)

Moxostoma macrolepidotum - Shorthead redhorse (I) * (3,14,58,78, 129)

Nocomis asper - Redspot chub (I) ** (8,11,12,14,20,21,32,58,61, 62,78,129)

Nocomis biguttatus - Hornyhead chub (G) *** (15,64,129)

Notemigonus crysoleucas - Golden shiner (G) *** (11,12,14,15,17, 21,58,61,62,64, 78,129)

Notropis atherinoides - Emerald shiner (G) *** (11,14,15,17,21, 58,61,64,78,129)

Notropis blennius - River shiner (I) *** (14,15,17,58,61,64)

Notropis boops - Bigeye shiner (I) *** (8,11,12,14,15,17,18,21, 58,62,64,78,120,129,130, 131)

Notropis buchanani - Ghost shiner (G) *** (14,17,58)

Notropis camurus - Bluntface shiner (I) *** (14,15,17,18,58,64, 78,129)

Notropis chrysocephalus - Striped shiner (I) ** (62,78,129,130)

Notropis cornutus - Common shiner (I) *** (14,15,64,129)

Notropis fumeus - Ribbon shiner (G) * (15)

Notropis galacturus - Whitetail shiner (IP) ** (129)

Notropis greenei - Wedgespot shiner (?) *** (8,14,15,17,18,58,62, 64,129)

Notropis lutrensis - Red shiner (B) *** (14,15,17,58,62,64,129)

Notropis nubilus - Ozark minnow (G) *** (8,11,12,14,15,17,18,20, 21,32,34,58,61,62,78,129, 132)

Notropis ozarcanus - Ozark shiner (?) ** (128,129)

Notropis pilsbryi - Duskystripe shiner (I) *** (8,11,12,14,20,21, 32,58,62,64,78, 130)

Notropis rubellus - Rosyface shiner (B) *** (8,11,12,14,15,17,18, 20,21,32,58,62,78, 129)

Notropis spilopterus - Spotfin shiner (B) *** (11,14,15,18,21,58, 64,78)

Notropis stramineus - Sand shiner (B) ** (14)

Notropis telescopus - Telescope shiner (I) ** (129)

Notropis umbratilis - Redfin shiner (I) *** (11,14,15,17,18,21, 58,62,64,78,129)

Notropis volucellus - Mimic shiner (B) *** (14,15,17,18,58,64, 128)

Notropis whipplei - Steelcolor shiner (I) ** (8,11,14,21,58,129, 131)

Notropis zonatus - Bleeding shiner (I) *** (15,17,18,129)

Noturus albater - Ozark madtom (I) ** (14,15,129)

Noturus eleutherus - Mountain madtom (I) *** (14,15)
Noturus exilis - Slender madtom (I) *** (8,12,14,17,18,20,32,58, 78,112,120,129,130)
Noturus flavater - Checkered madtom (B) ** (129)
Noturus flavus - Stonecat (IP) *** (8,14,15,58,64)
Noturus gyrinus - Tadpole madtom (IP) *** (14,15,58,64)
Noturus miurus - Brindled madtom (I) *** (14,15,17,58,64)

Noturus Nocturnus - Freckled madtom (I) *** (11,14,15,17,21,58, 64)
Percina caprodes - Logperch (I) *** (8,11,12,14,17,58,61,64,78, 129,130)
Percina copelandi - Channel darter (I) *** (14,17,58,61,129)
Percina evides - Gilt darter (I) ** (129)
Percina nasuta - Longnose darter (B) ** (129)
Percina phoxocephala - Slenderhead darter (I) *** (14,17,58,61, 64,78)
Percina shumardi - Silver darter (I) *** (14,17)
Phenacobius mirabilis - Suckermouth minnow (B) *** (8,12,14,15, 17,58,64)
Phoxinus erythrogaster - Southern redbelly dace (B) *** (8,11,12, 14,15,17, 20,21,32, 58,78, 129,131)
Pimephales notatus - Bluntnose minnow (B) *** (8,11,12,14,15,17, 21,58,62,64,78,120, 130,131)
Pimephales promelas - Fathead minnow (B) *** (8,12,14,15,17,58, 64,78,129)
Pimephales tenellus - Slim minnow (B) *** (11,14,18,58,129)
Pimephales vigilax - Bullhead minnow (B) *** (11,14,17,21,58)
Polydon spathula - Paddlefish (G) *** (14,15,17,58,61,64,129)
Pomoxis annularis - White crappie (IP) *** (3,8,14,17,23,58,61, 62,64,78,129,135)
Pomoxis nigromaculatus - Black crappie (PI) *** (3,14,17,58,61, 129,135)
Pylodictis olivaris - Flathead catfish (B) *** (3,14,15,17,58, 62,64,78,112,129)
Salmo gairdnerii - Rainbow trout (IP) *** (8,14,15,58,61,129)
Semotilus atromaculatus - Creek chub (IP) *** (8,11,12,14,15,17, 18,20,21,32,58,64, 78,131)
Stizostedion canadense - Sauger (PI) *** (3,14,58,61)
Stizostedion vitreum - Walleye (PI) ** (14,15,58,61,129)

Table 28. Number of species of the different feeding types of fish collected in the Illinois River and its tributaries before and after 1970.

Feeding Type	Number of Species	
	Before 1970	After 1970
Invertivores	34	37
Bottom Feeders	28	29
Invertivore-piscivores	14	17
Grazer	12	12
Piscivores	6	6
Piscivore-invertivores	4	7
Unknown	10	8
Total	108	116

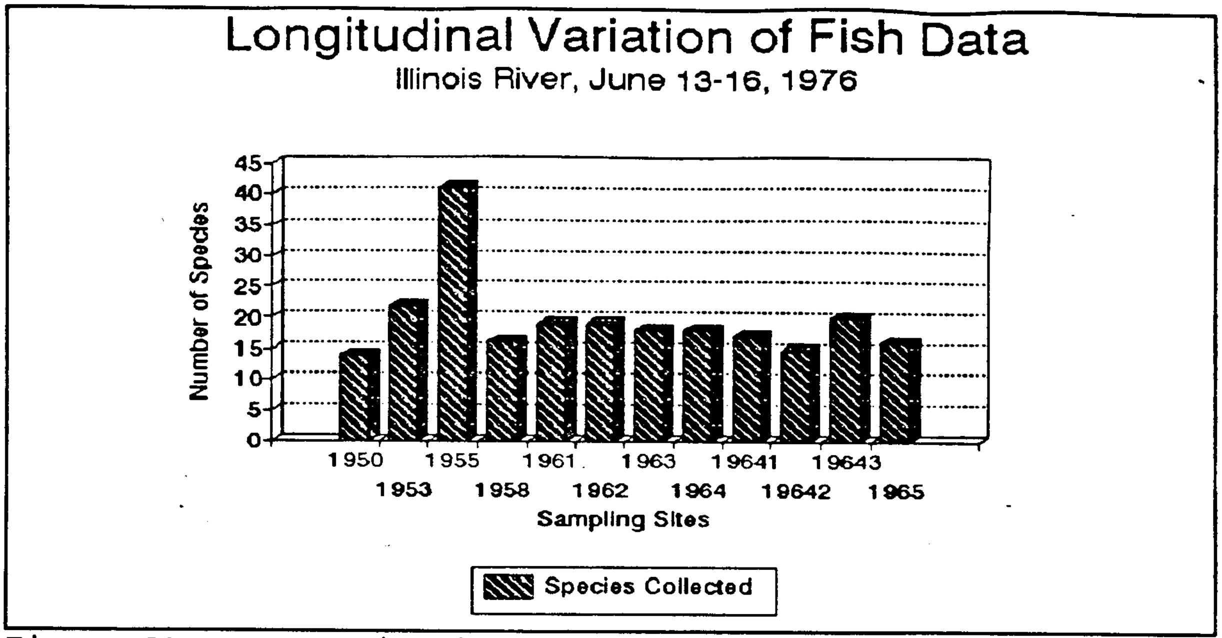

Figure 52. Longitudinal abundance of fish species along Illinois River on June 13-16, 1976 (OSDH, 1985).

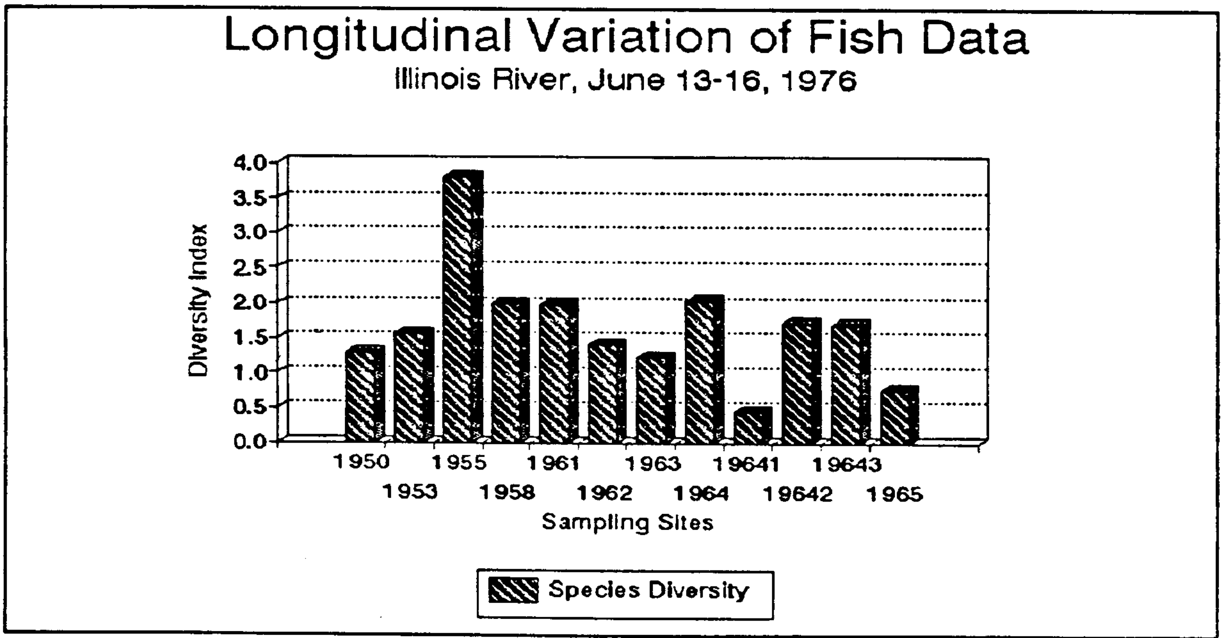

Figure 53. Longitudinal variation in diversity of fishes along Illinois River on June 13-16, 1976 (OSDH, 1985).

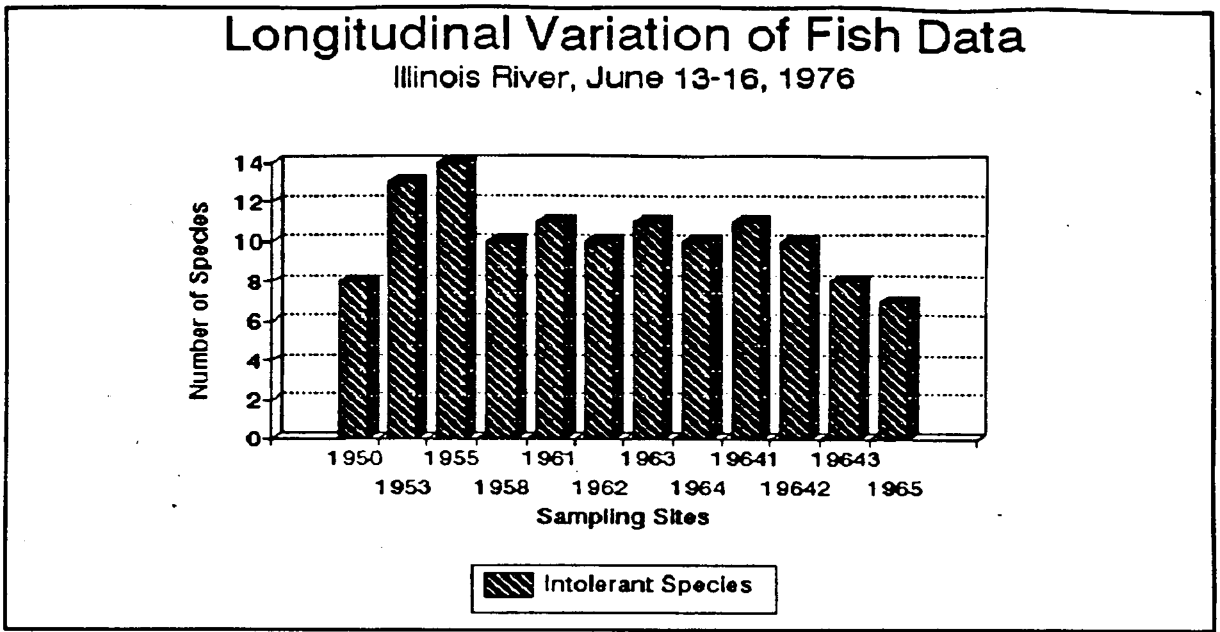

Figure 54. Longitudinal abundance of intolerant species of fish along the Illinois River on June 13-16, 1976 (OSDH, 1985).

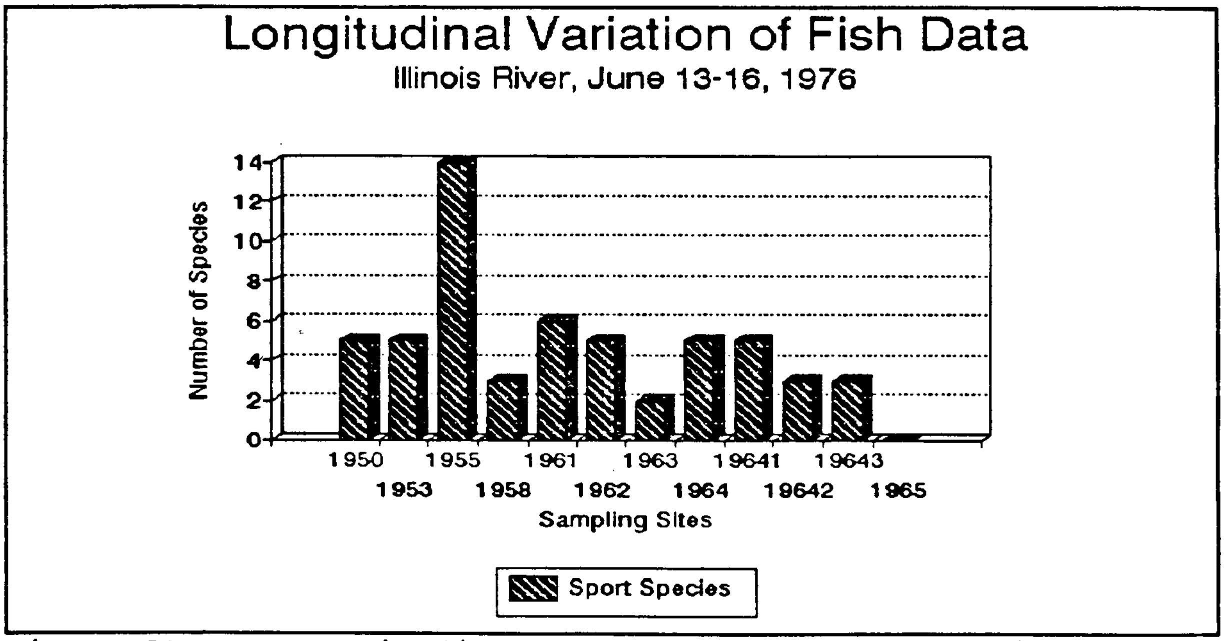

Figure 55. Longitudinal abundance of sports species of fish along the Illinois River on June 13-16, 1976 (OSDH, 1985).

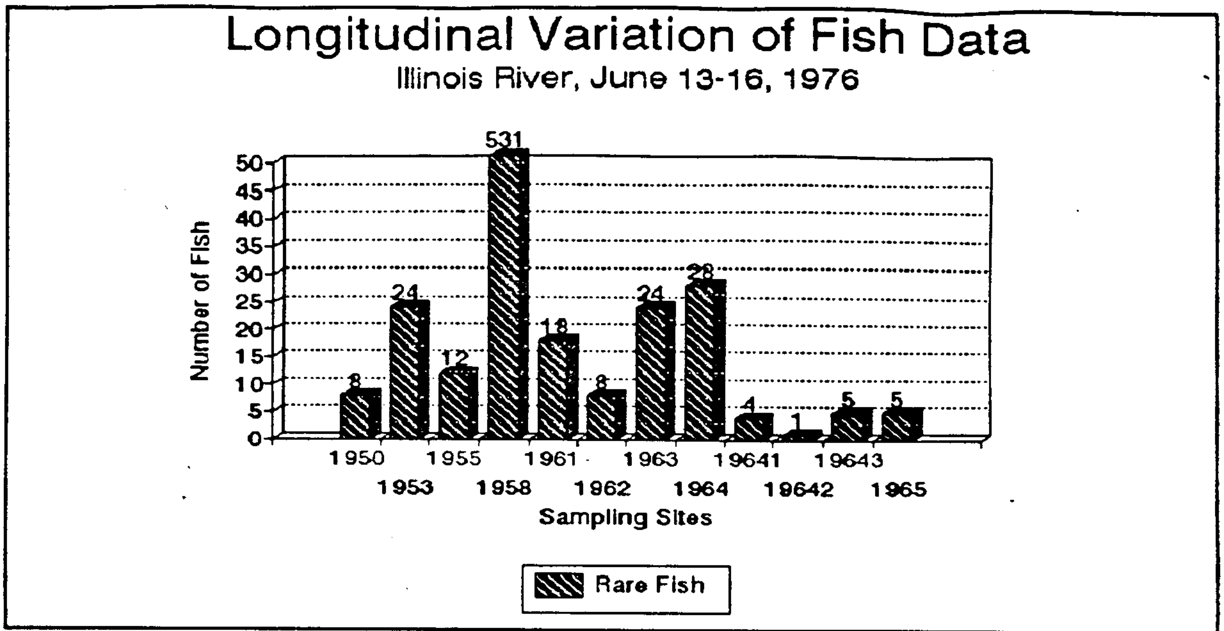

Figure 56. Longitudinal abundance of rare fish species along the Illinois River on June 13-16, 1976 (OSDH, 1985).

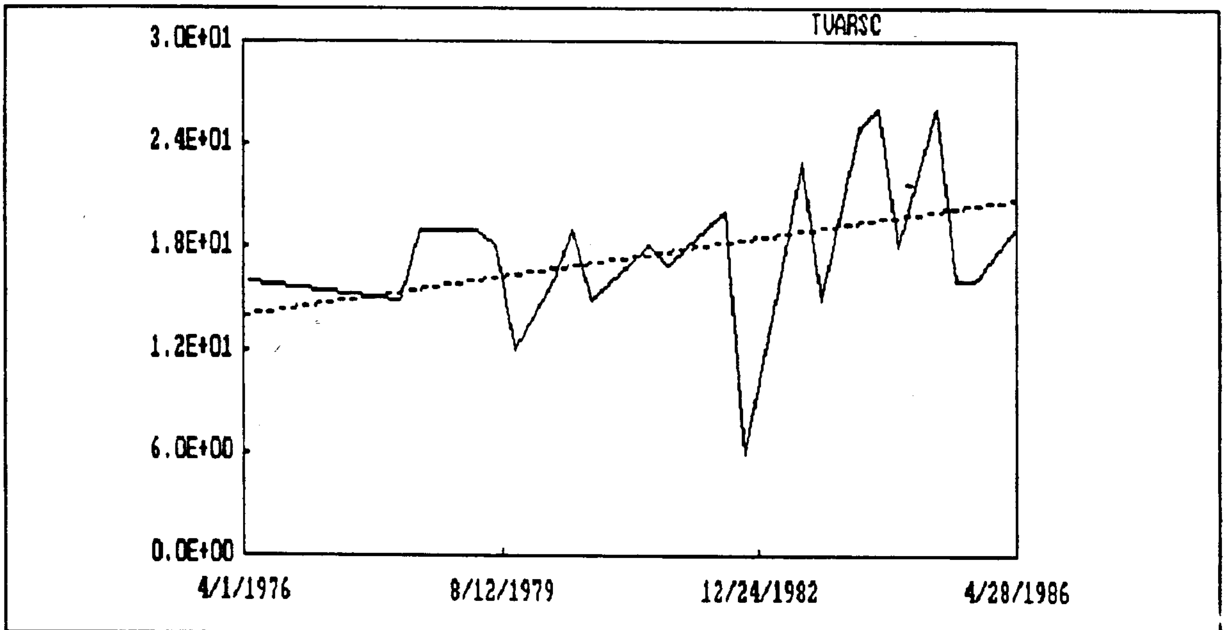

Figure 57. Trend analysis of species collected in the Illinois River at Tahlequah (USGS 1965) based on quarterly averages. Slope = 0.6667 species per year.

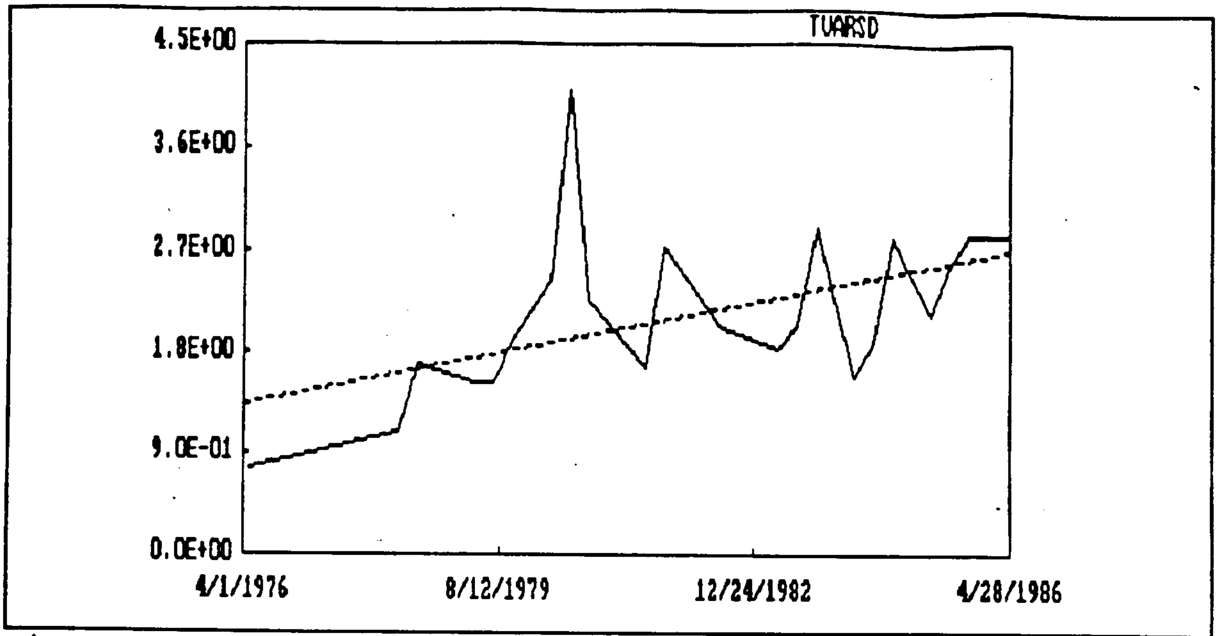

Figure 58. Trend analysis of species diversity from data collected at Tahlequah (USGS 1965) based on quarterly averages. Slope = 0.11800 units per year.

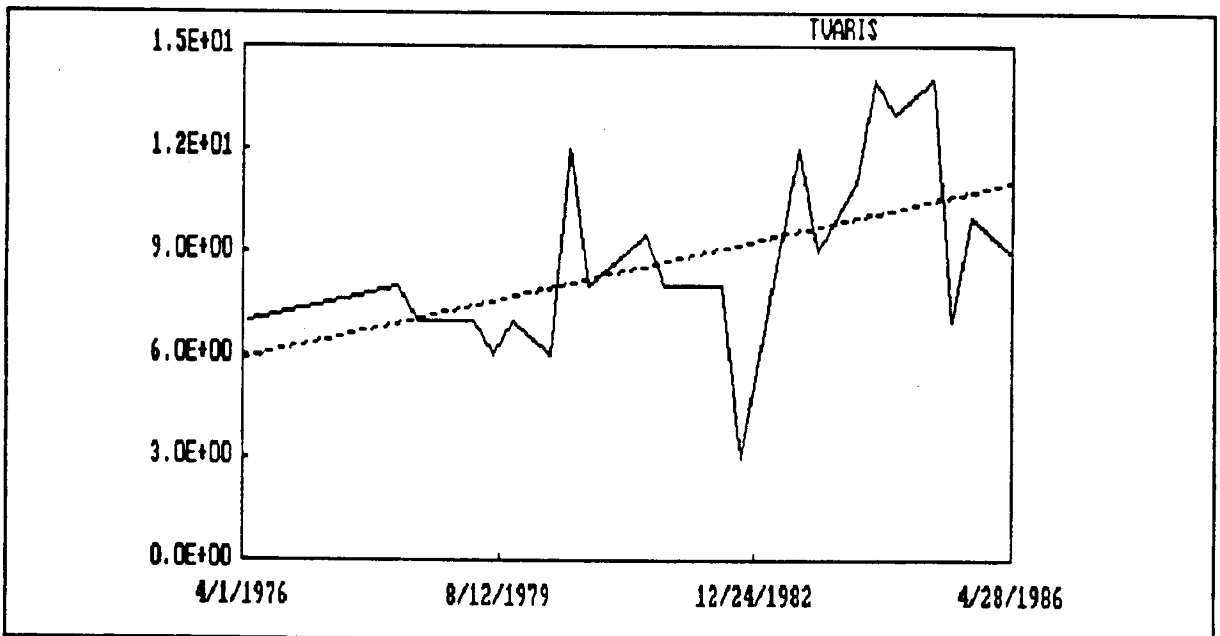

Figure 59. Trend analysis of intolerant species data collected at Tahlequah (USGS 1965) based on quarterly averages. Slope = 0.50000 species per year.

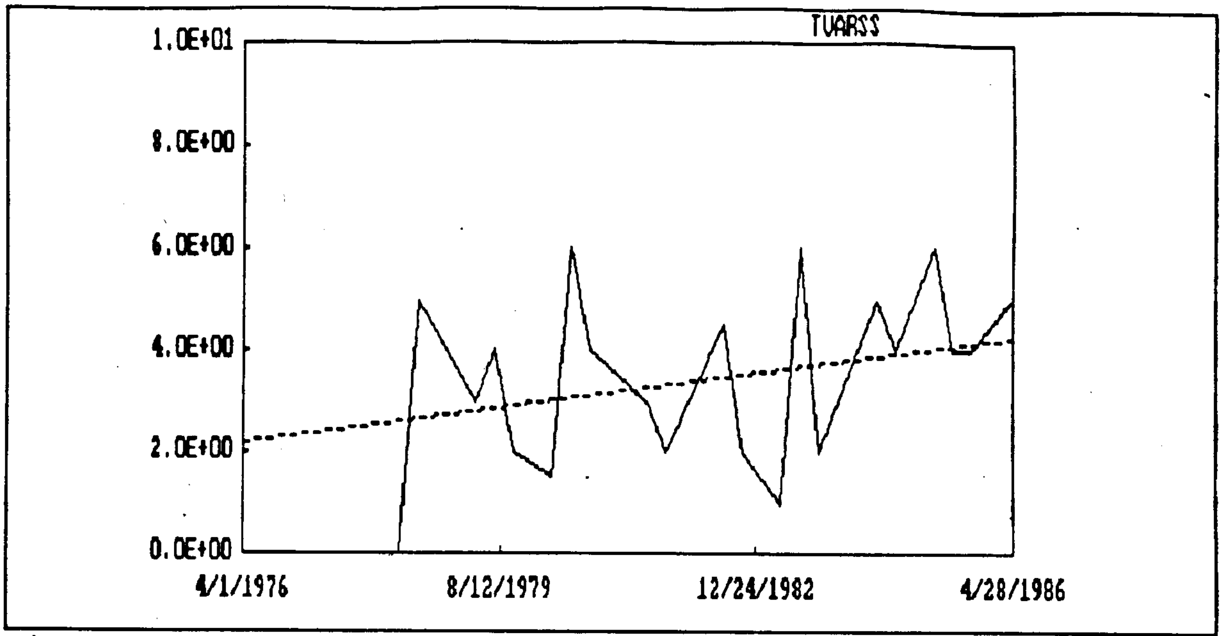

Figure 60. Trend analysis of sport species data collected at Tahlequah (USGS 1965) based on quarterly averages. Slope = 0.20000 species per year.

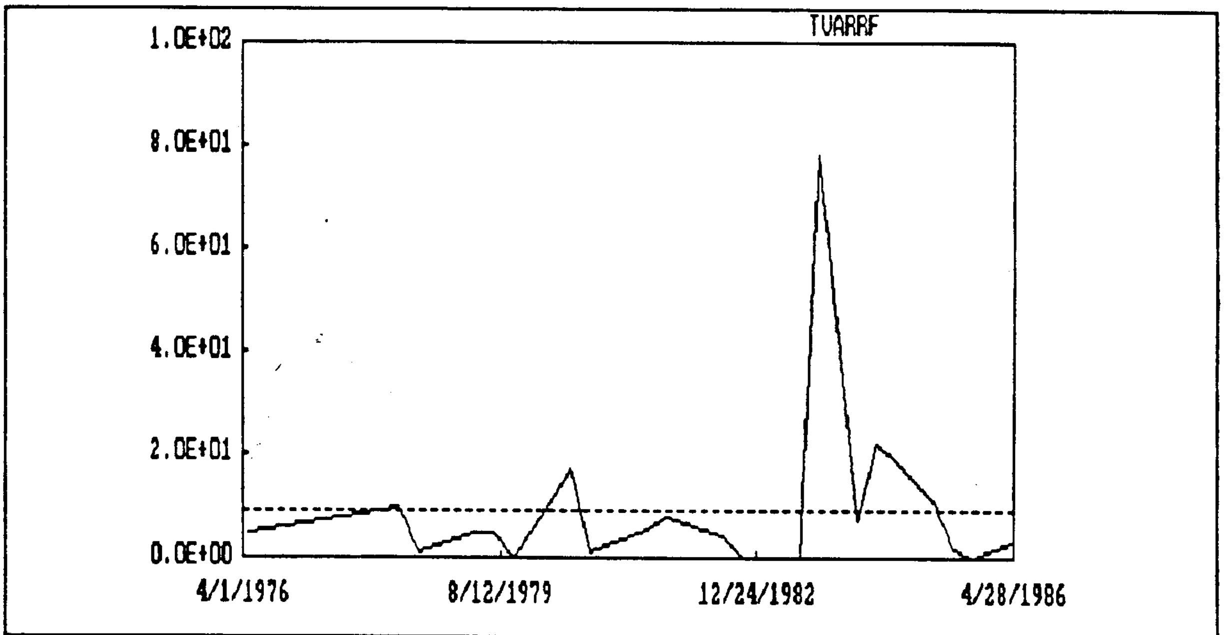

Figure 61. Trend analysis of rare fish data collected at Tahlequah (USGS 1965) based on quarterly averages. Slope = 0.00000 fish per year.

References Not in Appendix A

Lee, D. S. et al. 1980. Atlas of North American Fishes. North Carolina State Museum of Natur. Hist., Raleigh NC, 867 p.

Pflieger, W. L. 1975. The Fishes of Missouri. Missouri Dept. of Conserv., Jefferson City MO, 343 p.

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BENTHIC MACROINVERTEBRATES

Ecological Indicators

Emphasis is often placed on the assemblage of benthic macroinvertebrates in environmental studies for the following reasons (Wilhm and Dorris 1966, Wilhm 1967):

1) Most benthic macroinvertebrates have a relatively low ability to disperse and are unable to escape environmental stress.

2) Changes in the environment such as an increase of organic enrichment in an area usually reduces the number of species in an area. For example, many species of stoneflies, mayflies, and caddis flies may be eliminated by enrichment.

3) The numbers of a few tolerant species such as sludge worms and midges may increase drastically after an increase of organic enrichment since these organisms may use the organic substance as a food source and the predators of these organisms may be eliminated.

4) Mathematical equations called diversity indices have been used to summarize information about species and numbers of benthic macroinvertebrates. The decrease in the number of species and the increase in the number of a few species decrease the value of the diversity index. It has been demonstrated that values of species diversity of benthic macroinvertebrates exceeding 3.0 indicate clean water conditions, while values less than 1.0 suggest polluted conditions. Intermediate values suggest intermediate levels of pollution.

5) Since benthic macroinvertebrates have rather long life histories, the assemblage collected reflects conditions that occurred during their development.

6) These organisms are important in the aquatic food web and therefore directly affect fish populations.

Species Richness

A large number of species of benthic macroinvertebrates has been collected in the Illinois River and its tributaries (Table 29). In an annual study in 1971-72 in a headwater tributary to the Illinois River, McGraw (1978) collected 69 taxa (since it is extremely difficult to identify benthic macroinvertebrates to species, they are identified to the lowest taxonomic unit possible such as family or genus and thus the word taxa is used). Mayflies, stoneflies, and aquatic beetles were the most diverse groups present represented by 11,12, and 10 genera, respectively. Midges were found in substantial numbers throughout the year. Number of species and species diversity increased downstream. The absence or rarity of many taxa in the upper reaches and the low values of species diversity indicated the presence of adverse conditions such as disturbances of stream bed, particle size, and availability of food. The tributary supported a diverse assemblage of benthic macroinvertebrates.

The Arkansas Department of Pollution Control and Ecology (ADPCE and USEPA 1984) collected benthic macroinvertebrates in Spring Creek in July 1984 immediately upstream from the Springdale Sewage Treatment Plant (STP) and approximately 1 mile downstream from the discharge. Thirty-five taxa were identified in the sample collected above the STP outfall with a species diversity of 3.62 which indicates good quality water. At the downstream station, 13 taxa were collected and the diversity decreased to 1.15. One species comprised over 78% of the total number of organism collected. This is a typical example of the effect of a sewage input on the benthic macroinvertebrates. Unfortunately, no samples were taken further downstream to demonstrate the extent of recovery.

An extensive study was made in the middle reaches of the Illinois River by the Oklahoma State Department of Health in Summer 1976 (OSDH 1976, 1978, 1986). Samples were taken from the following three stations: 282, Lake Francis; 283, above the confluence of Flint Creek; 274, Comb's bridge; and 256, below Tahlequah and the confluence of Baron Fork. Collecting gear involved Surber samplers and Hester-Dendy artificial substrate samplers, and the sampling method differed at all stations. The benthic data indicated that adverse conditions existed in the lake. Only eight taxa were collected and species diversity was 0.8 (values less than 1.0 indicate stressed conditions). A pollution facultative midge larva (i.e. one that exists in clean water as well as in polluted environments) comprised 40% of the total numbers of individuals collected. Organisms limited to clean water environments such as species of stoneflies, caddis flies, and mayflies were absent from the collections. The organisms collected were typical of a silt-laden environment.

Considerably better conditions existed in the three riverine stations. Numbers of species collected were 23 at Station 283, 36 at 274, and 39 at 256, while species diversity values were 3.58, 3.84, and 3.69 (values exceeding 3.0 generally specify clean water conditions). Although species diversity values were similar at the three stations, additional analyses suggest that conditions varied. For example, the number of taxa of stoneflies decreased from the upstream to the downstream station. Many species of stoneflies and caddis flies are classed as pollution sensitive. More taxa were collected as pollution sensitive. More taxa were collected at the middle station than at the upper station and no caddis flies were collected at the station below Tahlequah, perhaps reflecting the increase of organic enrichment. The number of taxa of midges increased from the upstream to the downstream station. Many kinds of midges are more tolerant of organic enrichment. Although variation exists in the assemblages of benthic macroinvertebrates, some variation may have resulted from the different collecting methods used at the three stations.

We analyzed 28 articles that included studies of benthic macroinvertebrates and listed 139 taxa that have been collected in the Illinois River and its tributaries. Most of these studies addressed issues of interest to aquatic ecologists, but are of little use when evaluating issues of environmental water quality. They were not designed to address the issue of water quality.

Temporal changes

Unfortunately, few comprehensive studies which involved similar sampling methods and designs have been conducted. A study in the 1980's similar to the ODWC study in 1976 would have provided considerable information on changing conditions in the river. It would be essential for uniform collecting methods to be used at all stations. The Oklahoma State Department of Health published a 305(b) Technical Report for water years 1978-79 in which trends in benthic macroinvertebrate assemblages were described (OSDH 1980). These trends were determined from the OSDH study in 1976 and several smaller studies. They reported that no trend over time was apparent based on number of taxa, species diversity, or the number of dominant taxa. The lack of sufficient data probably prevented observing any trend.

In order to determine if changes occurred in the assemblage of benthic macroinvertebrates before and after 1970, feeding types of all species were determined from Aquatic Insects of North America (Merritt and Cummings 1978), Fresh water Invertebrates of the United States (Pennak 1953). Large changes in a particular feeding type such as grazers may indicate organic enrichment and the resulting build-up of algae.

Although the number of taxa increased abruptly in the headwaters after 1970, this reflects the greater number of studies after 1970 (Table 30). There was no substantial change in the number of taxa in the middle reaches. The greatest changes in feeding types before and after 1970 were the decrease in collector-gatherers and the increase in the collector-filterers in the middle reaches. The increase in collector-filterers may reflect an increase in the concentration of suspended food particles in the water column, while the decrease in collector-gatherers suggests a decrease in the organic material available on the stream bottom.

Summary

It is important to sample benthic macroinvertebrate populations in streams since they are valuable in the food chain and they provide information on current stream conditions as well as conditions that existed during their development. The use of these organisms as a "built-in bioassay" has been demonstrated many times. However, use of the benthic assemblage to provide information on stream conditions requires a standardized sampling program over a long period of time. Although this has been the practice for water quality parameters, no studies of benthic macroinvertebrates in the Illinois River have been conducted over long time periods. Few studies of benthic macroinvertebrates have been quantitative which would have enabled additional analyses. No consistent method of collecting organisms has been used. Variation has also existed in the stations sampled and almost all studies lacked a statistical design. Benthic data can provide important information about a stream system. However, unless a well-designed sampling program is developed and followed, few valid conclusions can be reached.

References Not in Appendix A

Merritt, R. W. and K. W. Cummins. 1978. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publ. Co, Dubuque, IA. 441 p.

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Wilhm, J. L. and T. C. Dorris. 1966. Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. Am. Midl. Natur. 76:427-449.

Wilhm, J. L. 1967. Comparison of some diversity indices applied to population of benthic macroinvertebrates in a stream receiving organic wastes. J. Water Pollut. Cons. Feb. 39:1676-1683.

Table 29. Species, feeding type[1], and time collected[2] and studies in which the species were collected[3] of benthos in the Illinois River and its tributaries

1: CG - Collector - Gatherers
   CF - Collector - Filterers
   P - Predators
   S - Shredders
   G - Grazers
   C - Collectors

2: * - Collected prior to 1970
   ** - Collected after 1970
   *** - Collected before and after 1970

3: File number (References are given by file number in Objective 1)

<u>Ablabesmyia</u> - Midge (P) *** (57,58,75)
<u>Acentropus</u> - Butterfly (S) * (75)
<u>Acroneuria</u> - Stonefly (P) ** (62,116)
<u>Agapetus</u> - Caddis fly (G) * (148,150)
<u>Agrionidae</u> - Damselfly (P) ** (139)
<u>Agria</u> - Damselfly (P) *** (75)
<u>Agrypnia</u> - Caddis fly (S) * (150)
<u>Allocapnia</u> - Stonefly (S) ** (116)
<u>Ancyronyx</u> - Elmid beetle (CG) * (75)
<u>Atherix</u> - Snipe fly (P) *** (75,148)
<u>Athripsodes</u> - Caddis fly (CG) * (150)
<u>Atrichopogon</u> - Biting midge (CG) *** (57,75,139)
<u>Baetis</u> - Mayfly (CG) *** (62,75,116,148)
<u>Berosus</u> - Water scavenger beetle (P) ** (139)
<u>Bezzia</u> - Biting midge (P) ** (162)
<u>Boyeria</u> - Dragonfly (P) * (75)
<u>Brachypter</u> - Stonefly (G) * (148)
<u>Caenis</u> - Mayfly (CG) *** (75,139,148)
<u>Cardiocladius</u> - Midge (P) * (148)
<u>Centroptilum</u> - Mayfly (CG) * (75)
<u>Cernotina</u> - Caddis fly (P) * (150)
<u>Chaoborus</u> - Phantom midge (P) ** (62,124)
<u>Chauliodes</u> - Alderfly (P) ** (179)
<u>Cheumatopsyche</u> - Caddis fly (CF) *** (57,58,75,116,148,150)
<u>Chimarra</u> - Caddis fly ( ) *** 57,58,75,116)
<u>Chironomus</u> - Midge (CG) *** (57,58,62,114,124,148)
<u>Chloroperlidae</u> - Stonefly (P) ** (139)
<u>Choroterpes</u> - Mayfly (CG) ** (139)
<u>Chrysops</u> - Housefly (CG) ** (62)
<u>Cladotanytarsus</u> - Midge (CG) ** (75)
<u>Clinotanypus</u> - Midge (P) ** (62)
<u>Corynoneura</u> - Midge (C) *** (57,58,75)

Corydalus - Dobsonfly (P) * (75,139)
Cricotopus - Midge (S) *** (57,58,75,148)
Cryptochironomus - Midge (P) *** (57,68,62,148)
Crynellus - Caddis fly (CF) *** (75,139)
Deronectes - Diving beetle (P) ** (139)
Diamesa - Midge (CG) *** (62,148)
Dibusa - Caddis fly (C) * (150)
Dicrotendipes - Midge (CG) *** (57,58,75)
Diplectrona - Caddis fly (CF) * (150)
Dubiraphia- Riffle beetle (CG) *** (62,75,124)
Ectopria - Water penny (G) *** (75,139)
Enallagma - Damselfly (CG) *** (75,124)
Enochrus - Scavenger beetle (C) * (75)
Ephemera - Mayfly (CG) *** (75,124)
Ephemerella - Mayfly (CG) *** (124,148)
Ephoron - Mayfly (CG) ** (57)
Eriocera - Crane fly (P) * (148)
Eukiefferiella - Midge (CG) *** (57,62,75)
Glyptotendipes - Midge (S) ** (57,58)
Helichus - Aquatic beetle (S) * (75,124,148)
Helicopsyche - Caddis beetle (G) *** (75,116)
Helopicus - Stonefly (P) ** (116)
Hemerodromia - Dance fly (P) *** (57,75)
Heptagenia - Mayfly (G) *** (57,62,75,124,148)
Hetaerina - Damselfley (P) * (75)
Hexagenia - Mayfly (G) *** (75,124)
Hexatoma - Crane fly (P) * (75)
Hydropsyche - Caddis fly (CF) *** (57,58,75,116)
Hydroptila - Caddis fly (P) * (75)
Isonychia - Mayfly (CF) *** (57,58,75,116,148)
Isoperla - Stonefly (P) *** (148)
Kiefferulus - Midge (CG) ** (57,58)
Labrundinia - Midge (P) * (75)
Lepidostoma - Caddis fly (S) * (150)
Leptocella - Caddis fly (S) * (150)
Leptophlebia - Mayfly (CG) * (116)
Limnophora - Anthomyiids (P) ** (139)
Lutrochus - Dryopid beetle (CG) ** (139)
Lype - Caddis fly (G) * (75,150)
Macronemum - Caddis fly (CF) * (150)
Macronychus - Elmid beetle (S) * (75)
Marilia - Caddis fly (S) * (75)
Metriocnemus - Midge (CG) * (148)
Micrasema - Caddis fly (S) * (150)
Microcylloepus - Elmid beetle (S) * (75,139)
Microtendipes - Midge (C) *** (58,75)
Mystacides - Caddis fly (CG) * (150)
Neocloeon - Mayfly (CG) ** (57)
Nemocapnia - Stonefly (S) ** (125)
Nemoura - Stonefly (S) ** (116)
Neoperlax - Stonefly (P) *** (57,75,116)
Neophylax - Caddis fly (G) * (150)

Neotrichia - Caddis fly (G) * (150)
Neureclipsis - Caddis fly (CF) *** (57,58,75)
Nigronia - Dobson fly (P) ** (139)
Nilotanypus - Midge (P) * (75)
Ochrontrichia - Caddis fly (CG) * (150)
Octogomphus - Dragonfly (P) ** (139)
Oecetis - Caddis fly (P) * (150)
Optioservus - Elmid beetle (G) ** (139)
Orthocladius - Midge (CG) *** (62,75,148)
Oxyethira - Caddis fly (P) * (150)
Paduniella - Caddis fly (CG) * (150)
Palpomyia - Biting midge (P) * (75)
Parachironomus - Midge (P) ** (58)
Paracladopelma - Midge (P) ** (57,58)
Paraleptophlebia - Mayfly (CG) ** (139)
Paratanytarsus - Midge (CG) * (75)
Perlesta - Stonefly (P) ** (116)
Phaenopsectra - Midge (G) ** (57,58)
Phasganophora - Stonefly (P) *** (75,139)
Podura - Springtail (CG) ** (179)
Polycentropus - Caddis fly (P) *** (57,125,148,150)
Polypedilum - Midge (S) *** (57,58,148)
Potamanthus - Mayfly (CG) *** (57,75)
Potamyia- Caddis fly (CF) * (150)
Potthastia - Midge (CG) * (75)
Procladius - Midge (P) ** (57,58)
Protoptila - Caddis fly (G) (150)
Psectrocladius - Midge (CG) *** (57,58,75)
Psephenus - Riffle beetle (G) * (62,75,139)
Pseudocloeon - Mayfly (G) *** (75,139,148)
Psychomyia - Caddis fly (CG) *** (57,58,139,150)
Ptilostomis - Caddis fly (S) * (150)
Pycnopsyche - Caddis fly (S) *** (75,116)
Pyralididae - Aquatic caterpillar (S) ** (179)
Rheotanytarsus - Midge (CF) *** (57,58,75)
Robackia - Midge (CG) * (75)
Setodes - Caddis fly (CG) * (150)
Sialis - Alderfly (P) ** (57,58,124)
Simulium - Black fly (CF) *** (75,116)
Sipholnurus - Mayfly (CG) ** (124)
Sphaeriidae - Fingernail clam (G) ** (57,58)
Stenonema - Mayfly (G) *** (57,58,62,75)
Stictochironomus - Midge (CG) ** (57,58)
Stratiomyiidae - Soldier flies (CG) ** (139)
Strophopteryx - Stonefly (G) ** (116)
Synclita - Butterfly (S) * (75)
Taeniopteryx - Stonefly (S) *** (134,148)
Tanytarsus - Midge (C) *** (57,58,62,75)
Thienemanniella - Midge (CG) * (75,148)
Thienemannimyia - Midge (P) * (75)
Tipula - Crane fly (S) *** (62,148)
Tribelos - Mayfly (CG) *** (57,58,75)

Tricorythodes - Mayfly (CG) *** (57,58,75,116)
Zealeuctra - Stonefly (S) ** (139)

Table 30. Number of taxa of the different feeding types of benthic macroinvertebrates in the Illinois River before and after 1970.				
Category	Headwaters		Midreaches	
	Before	After	Before	After
Collector-gatherers	14	15	20	7
Shredders	10	9	8	9
Grazers	9	7	8	7
Predators	9	30	16	18
Collectors-filterers	5	2	8	20
Collectors	1	1	4	4
Total	48	64	64	65

OBJECTIVE IV

IDENTIFY CAUSE OR CAUSES OF CHANGE IN WATER CLARITY

INTRODUCTION

As stated in Objective III, the data available did not indicate a general decrease in water clarity for the river. Clarity was poor and probably decreasing 1) in and below Lake Frances near the state border, 2) along Oklahoma Highway 10 where canoeing has become very intense, and 3) below the Tahlequah, Oklahoma sewage treatment facility effluent. The causes of decreases in water clarity at these specific sites seem obvious although cause and effect relationships are sometimes difficult to establish beyond any doubt. Lake Frances was (it no longer exists) an area where the flow diminished, which encouraged development of planktonic algae that probably contributed much of the turbidity. The convenience of having a good highway adjacent to the stream between SR 4 and SR 5 (see map), encouraged the development of an industry based on canoeing and related activities (camping, picnicing, swimming, etc.) that have degraded the water quality in that reach. The sewage treatment facility for Tahlequah appears to be unfavorably altering the water quality, including clarity, of the river for several miles.

Other insults to the riverine environment can contribute to localized water quality problems within the basin and these could eventually coalesce to produce a massive general problem that would be detectable at numerous routine monitoring sites. These include:

1) gravel removal from within the stream banks,

2) overgrazing and allowing beef and dairy cattle access to large areas of stream banks and streams,

3) road construction and maintenance practices within the basin,

4) bridge construction practices which allow runoff from roads and fields to enter streams,

5) driving vehicles directly into and across streams, especially for loading and unloading canoes, loading gravel, building bridges, and agricultural access,

6) damage to or removal of riparian (streamside) vegetation which stabilizes stream banks, shades the stream and serves as a buffer,

7) cultivation (plowing or discing) of fields which are regularly flooded by the river,

8) excessive and/or improper application of animal wastes to pastures adjacent to streams,

9) improper siting, installation and maintenance of septic

tank fields,

10) improper siting, installation and maintenance of liquid animal waste holding facilities,

11) failure to properly upgrade, maintain and operate sewage treatment facilities.

CHEMICAL WATER QUALITY

Water Clarity

Data for the indicators of water clarity (turbidity, nonfilterable residue, suspended solids, chlorophylls, and phytoplankton) collectively reveal that the water was less clear in the three specific reaches identified in previous chapters. But no trend of loss of clarity for the entire river was substantiated. Causes for the changes in water clarity at the specific sites seem obvious due to their locations: one was in a small, eutrophic reservoir, another in an area with an unusually large amount of canoeing and associated activities, and the third downstream from a sewage outfall.

It would appear that suspended solids have not changed significantly along the Illinois River during the period of record. While there were significant increases at some locations in response to either nutrient enrichment (e.g., Lake Frances and below Tahlequah STP) or possibly other anthropogenic activities (e.g., at SR-5), there was no overall statistically significant change in suspended solids along the length of the river. Clarity of water is a perceptual parameter that is difficult to quantify. There may have been a general change in the aesthetic quality of the water, but the data available do not support this contention for most of the river.

The calculated summary statistics for annual loadings of total nonfilterable residue transported down the Illinois River present some indication of the combined impact of the anthropogenic activities in the basin. The mean load of suspended materials transported into Lake Frances was calculated to be 11,850 tons/year (Table 31). The total quantities generally decreased downstream; however, it is obvious that significant quantities of suspended materials were being transported into the downstream reservoirs of Lake Frances and Lake Tenkiller.

There was a statistically significant decrease in the long-term loading of suspended materials at USGS 07194800, although the actual quantitative decrease of 0.42 kg/yr appeared to be relatively small (Table 32). Only two sampling stations exhibited a statistically significant increase in annual loading rates for non-filterable residues, i.e., SR-0.5 in Lake Frances and SR-5 on the Illinois River. The decreasing long-term trend of suspended material annual loading rates at most of the other sampling stations was insignificant.

Table 31. Summary statistics for calculated annual total non-filterable residue in kg/yr for period of record.

Source	Annual Residue Loadings, (kg/yr)			
	N	Mean	Median	SD
USGS 07194800	110	4161948	169675	21374058
USGS 07195000	79	9786521	0*	74351814
USGS 07195400	54	14913991	1150000	54592433
USGS 07195500	106	41587369	3930000	279966579
USGS 07196000	90	8232398	125500	73204279
USGS 07196500	106	47199552	2430000	318335231
USGS 07197000	106	5806253	240900	33678327

* missing several years of data

APPENDIX A

ILLINOIS RIVER BASIN REPORTS AND STUDIES

ADPCE. Arkansas water quality standards. Arkansas Department of Pollution Control and Ecology. Little Rock, AR. Key Words: water quality, and UA. File Number: 109.

ADPCE. 1984. Wasteload evaluation report for Rogers' discharge into Osage Creek. pp. 50+. Arkansas Dept. of Pollution Control and Ecology. Key Words: water quality. File Number: 19.

ADPCE, and USEPA. 1984. Wasteload evaluation report for Springdale's discharge into Spring Creek, and proposed STP upgrade information. ADPCE and USEPA. Key Words: hydraulics, water quality, fish, and benthics. File Number: 20.

ADPCE. 1984. Wasteload evaluation report for Fayetteville's proposed discharge into the White River and an unnamed tributary of Mud Creek. pp. 45. Arkansas Department of Pollution Control and Ecology. Little Rock, AR. Key Words: water quality, and UA. File Number: 110.

Aggus, L.R., and Warren, L.O. 1965. Bottom organisms of the Beaver Reservoir Basin. A pre-impoundment study. Journal of the Kansas Entomological Society. 38:163-178. Key Words: UA. File Number: 38.

Andreasen, J.K. 1988. Contaminant residues in fish from northeastern Oklahoma. pp. 14. U.S. Fish and Wildlife Service, Ecological Services. Tulsa, OK. Key Words: fish, and water quality. Comments: Fish were analyzed for metals and pesticides. File Number: 65.

AOARCC. 1985. Findings of fact, conclusions of law and commission order. Arkansas-Oklahoma Arkansas River Compact Commission. pp. 25. Ark.-Ok. Arkansas River Compact Commission. Fayetteville, AR. Comments: Application of the State of OK and the Oklahoma Scenic Rivers Commission hearing in Fayetteville. AORCC = Arkansas-Oklahoma Compact Commission. File Number: 93.

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Blanz, R.E., Hoffman, C.E., Kilambi, R.V., and Liston, C.R. 1969. Benthic macroinvertebrates in cold tailwaters and natural streams in the state of Arkansas. Proc. 23rd Ann. Conf. Southeast. Assoc. Game and Fish Comm.. 1:281-292. File Number: 114.

Blanz, R.E. 1969. Physico-chemical factors and benthic macroinvertebrates in cold tailwaters and natural streams in the state of Arkansas. Masters Thesis. pp. 77. University of Arkansas. Fayetteville, Arkansas. Key Words: UA. File Number: 141.

Bowen, J. 1978. Nutrient contributions to the Illinois River in Arkansas. M.S. Thesis. pp. 133. University of Arkansas. Fayetteville, AR. Key Words: water quality, and UA. File Number: 115.

Breisch, W.B. 1966. Oklahoma outdoor recreation plan. pp. 192. Breisch Engineering. Tulsa, OK. Comments: No data; general reference to Illinois River Basin area for outdoor recreation. File Number: 47.

Brown, A.V., and Ricker, J.P. 1982. Marcoinvertebrate utilization of leaf detritus in a riffle of the Illinois River, Arkansas. Ark. Acad. Sci. Proc.. 36:10-13. Key Words: benthics. File Number: 116.

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Brown, A.V., and Armstrong, M.L. 1985. Propensity to drift downstream among various species of fish. J. Freshwat. Ecol.. 3(1):3-17. Key Words: drift, and fish. File Number: 112.

Brown, A.V., Limbeck, R.L., and Schram, M.D. 1989. Trophic importance of zooplankton in streams with alluvial riffle and pool geomorphometry. Arch. Hydrobiol. 114(3):349-367. Key Words: zooplankton, and geomorphology. File Number: 168.

Brussock, P.P., Willis, L.D., and Brown, A.V. 1985. Flow reduction may explain sporadic occurance of Craspedacusta sowerbyi (Trachylina) medusae. Ark. Acad. Sci. Proc. 39:120. Key Words: hydraulics, benthics, and UA. File Number: 118.

Brussock, P.P., Brown, A.V., and Dixon, J.C. 1985. Channel form and stream ecosystem models. Water Resources Bulletin. 21(5):859-866. Key Words: geomorphology. File Number: 167.

Brussock, P.P. 1986. Macrodistribution and movements of benthic macroinvertebrates in relation to stream geomorphology. Phd. dissertation. University of Arkansas. Fayetteville, Arkansas. Key Words: benthics, geomorphology, and UA. File Number: 125.

Brussock, P.P., Willis, L.D., and Brown, A.V. 1988. Leaf decomposition in an Ozark cave and spring. J. Freshwat. Ecol.. 4 (3):263-269. Key Words: benthics, and water quality. File Number: 117.

Bryant, C.T., Ludwig, A.H., and Morris, E.E. 1985. Ground water problems in Arkansas. Water Resources Investigation Report 85-4010. pp. 24. USGS, ADPCE, AS&WCC. Little Rock, AR. Key Words: groundwater, water quality, and soils. Comments: AS&WCC = Ark Soil and Water Conservation Commission; Maps of recharge zones, potential contamination sources, principal gw problems, depth to water, area of low yields, geology and formation characteristics. File Number: 138.

Buchanan, T.M. 1973. Key to the fishes of Arkansas. 1: Ark. Game and Fish Comm.. Little Rock AR. Key Words: fish, and UA. File Number: 126.

Burks, S. L. 1987. QUAL2E modeling of the Illinois River, Oklahoma. pp. 52. U. S. Army Corps of Engineers. Tulsa, OK. Key Words: water quality, and hydraulics. Comments: This report may have a different title; we have the draft. File Number: 35.

Burks, S.L., Wilhm, J., OSU, Summerfelt, R., Miller, R., Badger, D., and Dorris, T. 1975. Proposals: Water quality studies of the Illinois River not funded. pp. 20. OSU - Water Quality Reserach Laboratory. Stillwater, OK. File Number: 100.

Burr, B.M., and Pflieger, W.L. 1979. Campostoma Oligolepis and Notropis Ozarcanus (Pisces:Cyprinidae), two additions to the known fish fauna of the Illinois River, Arkansas and Oklahoma. The Southwestern Naturalist. 24(2):380-383. Key Words: fish. File Number: 128.

CH2M/HILL, and MCCELLAND/CONSULT/ENGR/INC. 1984. 201 facilities plan for city of Fayetteville, Arkansas. CH2M HILL and McClelland Consulting Engineers, Inc.. Key Words: water quality. Comments: LImited data. See Dr. Dan Badger, 322 Ag Hall, OSU. File Number: 63.

Cloutman, D.G., and Olmsted, L.L. 1976. The fishes of Washington County, Arkansas. No. 39: pp. 109. Arkansas Water Resources Research Center, U. of A.. Fayetteville, Arkansas. Key Words: fish. File Number: 129.

Cox, W.R. 1975. Flint Creek in Oklahoma: A habitat study of its darters, minnows, and other native fishes. Masters Thesis. pp. 91. University of Tulsa. Tulsa, OK. Key Words: fish. File Number: 8.

Degrave, G.M. 1985. Comprehensive basin-wide study plan for the Illinois River system. Work Assignment No. 35, Contract 68-01-6986. pp. 19. Battelle Columbus Laboratories. Washington, D.C.. Comments: No Data, recommendations only: plan of study. File Number: 41.

Deppert, D.L. 1978. The effect of striped bass predation and water quality on the rainbow trout fishery of the lower Illinois River. Masters Thesis. pp. 103. University of Oklahoma. Norman, OK. Key Words: fish, and water quality. File Number: 6.

Ebert, D.J., Brown, A.V., and Fielder, C.B. 1987. Distribution of fish within headwater riffles of the Illinois River system, Washington County, Arkansas. Key Words: fish, & benthics. File Number: 120.

Felley, J.D., and Hill, L.G. 1983. Multivariate assessment of environmental preferences of cyprinid fishes of the Illinois River, Oklahoma. The American Midland Naturalist. 109(2):209-221. Key Words: fish. File Number: 131.

Finnell, J.C. 1954. Dissolved oxygen and temperature profiles of Tenkiller Reservoir and tailwaters with consideration of these waters as a possible habitat for rainbow trout. Proceedings of the Oklahoma Academy of Science. 34:65-72. Key Words: fish. File Number: 151.

Freiwald, D.A. 1985. Average annual precipitation and runoff for Arkansas, 1951 - 1980. Water Resources Investigations Report 84-4363. USGS. Little Rock, AR. Key Words: maps, and hydraulics. Comments: One large display with precipitation and runoff maps, tables of totals; Arkansas Only. File Number: 158.

Freiwald, D.A. 1987. Streamflow gain and loss of selected streams in northern Arkansas. Water Resources Investigations Report 86-4185. USGS. Little Rock, AR. Key Words: maps, and hydraulics. Comments: Series of maps with descriptions and narative of gains and losses. File Number: 157.

Gakstatter, J.H. and Katko, A. 1986. An intensive survey of the Illinois River (Arkansas and Oklahoma) in August 1985. pp. 141. U.S. EPA, Environmental Research Laboratory--Duluth. Duluth, MN. Key Words: water quality, algae, and hydraulics. File Number: 60.

Geihsler, M.R., Short, E.D., and Kittle, P.D. 1975. A preliminary checklist of the fishes if the Illinois River, Arkansas. Arkansas Academy of Science Proceedings. 29:37-39. Key Words: fish. File Number: 78.

Gelwick, F.P. 1987. Longitudinal and temporal patterns of riffle and pool fish assemblages in an Ozark stream, Delaware county, Oklahoma. Masters Thesis. pp. 93. The University of Tulsa. Tulsa, Oklahoma. Key Words: fish, and water quality. File Number: 132.

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Gordon, M.E., Mackie, G.L., and Brown, A.V. 1980. <u>Pisidium</u> <u>Fallax</u> (Bivalvia:Pisidiidae) in the southwestern Ozark plateaus. The Nautilus. 94:120-121. Key Words: benthics. File Number: 123.

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Heimann, D.C., and Tortorelli, R.L. 1988. Statistical summaries of streamflow records in Oklahoma and parts of Arkansas, Kansas, Missouri, and Texas through 1984. Water Resources Investigations Report 87-4205. pp. 387. U.S. Geological Survey, Water Resources Division. Oklahoma City, OK. Key Words: hydraulics. File Number: 4.

Heiple, L.R., and Jeffus, H.M. 1970. Water resources planning Study for Arkansas and Oklahoma. Publication No. 7. pp. 64. Arkansas Water Resources Research Center. Key Words: water quality, and UA. File Number: 134.

Hern, S.C., Lambou, V.W., Morris, M.K., Taylor, W.D., and Williams, L.R. 1979. Distribution of phytoplankton in Oklahoma lakes. EPA-600/3-79-068. pp. 60. U.S. Environmental Protection Agency. Las Vegas, NV. Key Words: algae. File Number: 13.

Hines, M.S. 1975. Flow-duration and low-flow frequency determination of selected Arkansas streams. Water Resources Circular No. 12. pp. 75. USGS, AGC. Little Rock, AR. Key Words: hydraulics. File Number: 156.

Hubbs, C.L., and Ortenburger, A.I. 1929. Notes on Oklahoma fishes. University of Oklahoma Biological Survey Bulletin. 434:Key Words: fish. Comments: The journal was so old it was difficult to handle without the pages tearing; therefore only the title pages were xeroxed. The origional is in the OSU Library. File Number: 107.

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Isley, F.B. 1925. The freshwater mussel fauna of eastern Oklahoma. University of Oklahoma Bulletin N.S.. 322:43-118. Key Words: benthics, and UA. File Number: 136.

Janacek, W.J. 1985. Water analysis report. pp. 75. OSDH. Oklahoma City, OK. Key Words: hydraulics, and water quality. Comments: Tahlequah STP, USGS 1970, USGS 1970; monthly or semimonthly from 08/06/85 to 09/29/86. File Number: 92.

Jenkins, R.M., Leonard, E.M., and Hall, G.E. 1952. An investigation of the fisheries resources of the Illinois River and pre-impoundment study of Tenkiller Reservoir, Oklahoma. Report # 26. pp. 136. Oklahoma Fisheries Research Laboratory. Norman, OK. Key Words: fish, and water quality. File Number: 3.

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Kurklin, J.K. 1979. Statistical summaries of surface water quality data for selected sites in Oklahoma through the 1975 water year. pp. 171. OWRB. Oklahoma City, OK. Key Words: water quality, and hydraulics. Comments: Uses USGS stations and data; Gore station only. File Number: 43.

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Lyhane, T.E. 1987. Hydrologic investigation of the Illinois River. Technical Report 87-3. pp. 21. Oklahoma Water Resources Board, Stream Water Division. Oklahoma City, OK. Key Words: hydraulics. File Number: 66.

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Neely, B.L. Jr. 1987. Annual peak discharges and stages through 1984 for gaging stations In Arkansas. Open-File Report 87-208. pp. 125. USGS, AGC, ASH&TD. Little Rock, AR. Key Words: hydraulics. Comments: AGC = Ark. Geological Commission; ASH&TD = Ark. State Highway and Transportation Department. File Number: 155.

Noland, S. 1976. An investigation of fecal contamination in the Illinois River in Arkansas. pp. 78. University of Arkansas MS Thesis. Fayetteville AR. Key Words: water quality, and UA. File Number: 142.

Nolen, S., and USACE. 1986. STORET hard copy printout of water quality data. STORET, USACE. Tulsa, OK. Key Words: water quality, and hydraulics. Comments: Two separate printouts. Stations SR05, SR1, SR2, SR3, SR4, SR4.5, SR5, SR6.3, SR6.5, SR7.5, 07195500, 07196500, 07198000, 07196000, 07197000, SR6, SR7, SR8, SR9, ARK61, ARK62, ARK63, ARK64, ARK65, ARK06. File Number: 73.

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OCC. 1987. A spatial analysis of sediment arsenic data for Oklahoma. pp. 21+. OCC, Water Quality Program. Oklahoma City, OK. Key Words: water quality. Comments: This paper can be found in Dr. Dan Badger's office. 322 Ag Hall, OSU. File Number: 27.

OCC. 1987. Battle Creek nonpoint source study. Interim report. pp. 50+. Oklahoma Conservation Commission. Oklahoma City. Key Words: fish, water quality, and hydraulics. Comments: Data summaries. File Number: 32.

OCC. 1988. The Battle Creek project. Final report, supported under FY 1987 106 Task 215. pp. 14. Oklahoma Conservation Commission. Oklahoma City. Key Words: water quality. Comments: No data. File Number: 30.

OCC. 1989. Confined animal count, Illinois River Basin, Oklahoma. pp. 11. Oklahoma Conservation Commission. Oklahoma City, OK. Comments: Data only; no report. Poultry, and dairy; total number and quantity of waste. Constituents and estimated quanity of animal waste. File Number: 85.

ODPC. 1980. Municipal point source inventory, 1980. pp. 11. ODPC. Oklahoma City,OK. Comments: Point source location descriptions. File Number: 79.

ODPC. 1981. The Illinois River basin. A comprehensive look at agency activities. pp. 113. ODPC. Oklahoma City, OK. Comments: No data; lists agencies involved with Illinois River studies. File Number: 86.

ODWC. 1986. West Branch Creek fish kill, Adair county. pp. 13. Oklahoma Department of Wildlife Conservation. Oklahoma City. Key Words: water quality. File Number: 33.

ODWC. 1987. Ballard Creek fish kill. pp. 50+. Oklahoma Department of Wildlife Conservation. Oklahoma City. Key Words: fish, & water quality. Comments: Communications between state agencies, interium reports, data appendices etc., all grouped together. File Number: 34.

ODWC. 1988. Factors influencing fish populations in Oklahoma waters: Movements of striped bass in the Arkansas River downstream from Keystone Reservoir. Job No. 11, Federal Aid Project No. F-41-R: July 1, 1986 - June 30, 1988. pp. 25. Oklahoma Dept Of Wildlife Conservation. Oklahoma City, OK. Key Words: fish. Comments: Refers to only one tagged fish acptured in Illinois River below Tenkiller Lake. File Number: 48.

OKC-CHD. 1982. Biotrend data. pp. 15. OKC-County Health Department. Oklahoma City, OK. Key Words: algae, & benthics. Comments: OKCCDH = Oklahoma City County Health Department. Chlorophyll, periphyton, phytoplankton, and benthic macroinvertebrate data for 1980 and 1982 at USGS 1965. File Number: 75.

OKSCORP. 1976. Oklahoma scenic rivers. A first look. pp. 118. Oklahoma Tourism and Recreation Department. Oklahoma City, OK. Key Words: hydraulics, & water quality. Comments: Very limited data. OKSCORP = Oklahoma Statewide Comprehensive Outdoor Recreation Plan. See Dr. Dan Badger, 322 Ag Hall, OSU. File Number: 51.

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OSDH. 1978. Surface water quality assessment for Oklahoma. Water year 1977, 305(b) Report. pp. 338. OSDH, State Water Quality Laboratory. Oklahoma City, OK. Key Words: water quality, fish, algae, and benthics. File Number: 57.

OSDH. 1978a. Water quality of the Illinois River and Tenkiller Reservoir, June 1975 - October 1977. pp. 152. OSDH, State Water Quality Laboratory. Oklahoma City, OK. Key Words: water quality, benthics, algae, fish, and hydraulics. File Number: 58.

OSDH. 1980. 305(b) technical report for Oklahoma. Water years 1978 - 1979. pp. 129. OSDH, State Water Quality Laboratory. Oklahoma City, OK. Key Words: water quality, fish, and benthics. File Number: 55.

OSDH. 1981. Toxics monitoring survey of Oklahoma reservoirs, 1980-1981. Final report. pp. 122. OSDH. Oklahoma City, OK. Key Words: fish, and water quality. Comments: No data tables; summaries only. File Number: 45.

OSDH. 1982. Public water supply report, 1982. OSDH, Environmental Health Services. Oklahoma City, OK. Key Words: water quality. Comments: The report is in four volumes and alphabetized by county. File Number: 16.

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Woomer, Neal. M. 1986. Quantitative ecology of the phytobenthos of two Ozark streams. pp. 125. University of Arkansas Ph.D. Dissertation. Fayetteville, AR. Key Words: algae, water quality, hydraulics, and UA. File Number: 152.

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APPENDIX B

GRAPHIC ILLUSTRATION OF LONGTERM TEMPORAL TRENDS IN TOTAL PHOSPHORUS CONCENTRATION IN ILLINOIS RIVER

LIST OF FIGURES

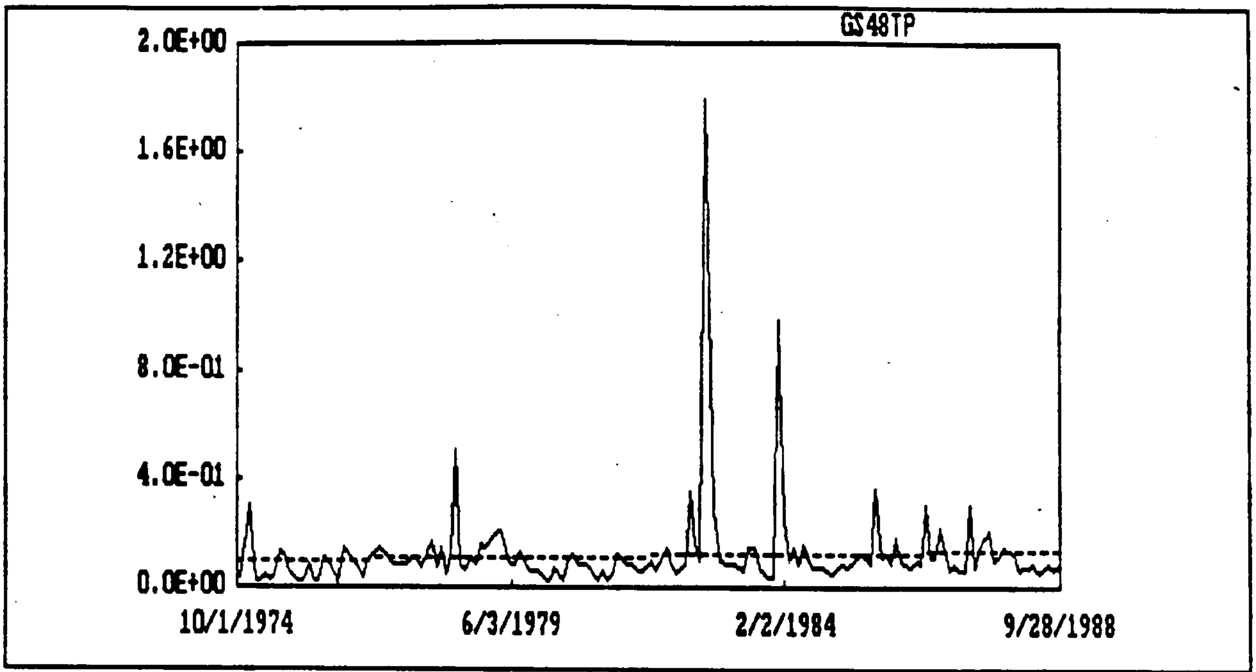

Figure B-1. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at USGS 07194800. Seasonal Kendall Sen Slope Estimate = 0.002 mg/l/yr.

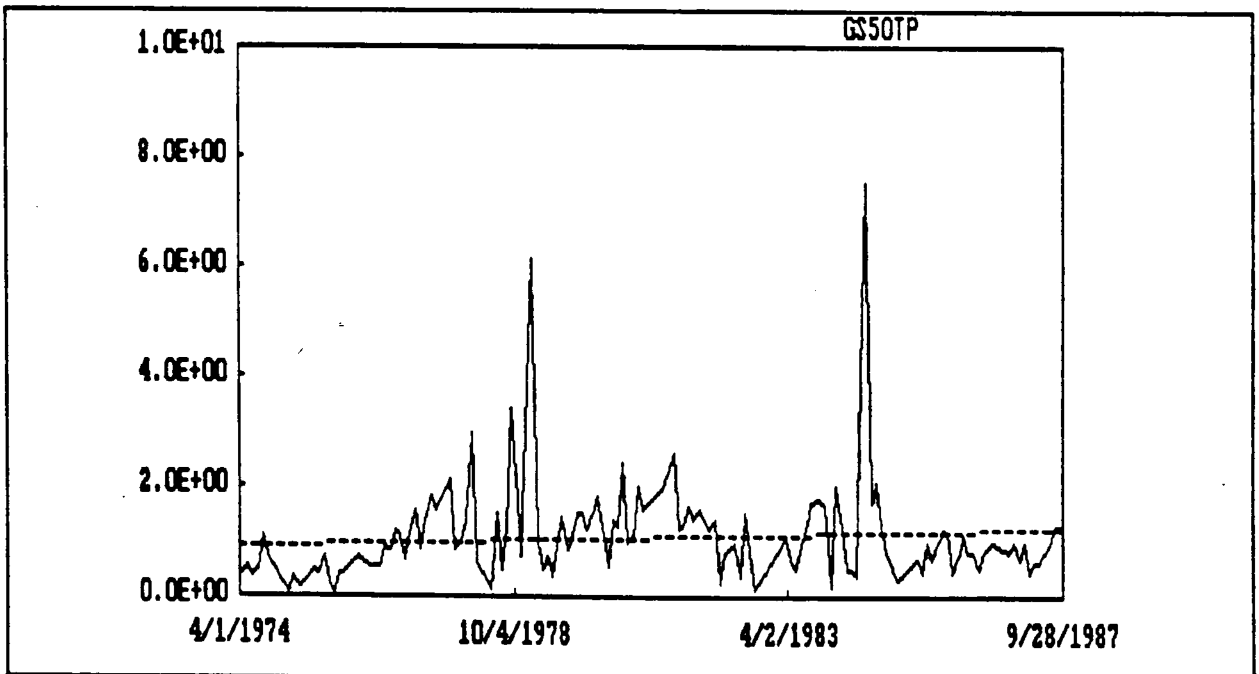

Figure B-2. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at USGS 07195000. Seasonal Kendall Sen Slope Estimate = 0.022 mg/l/yr.

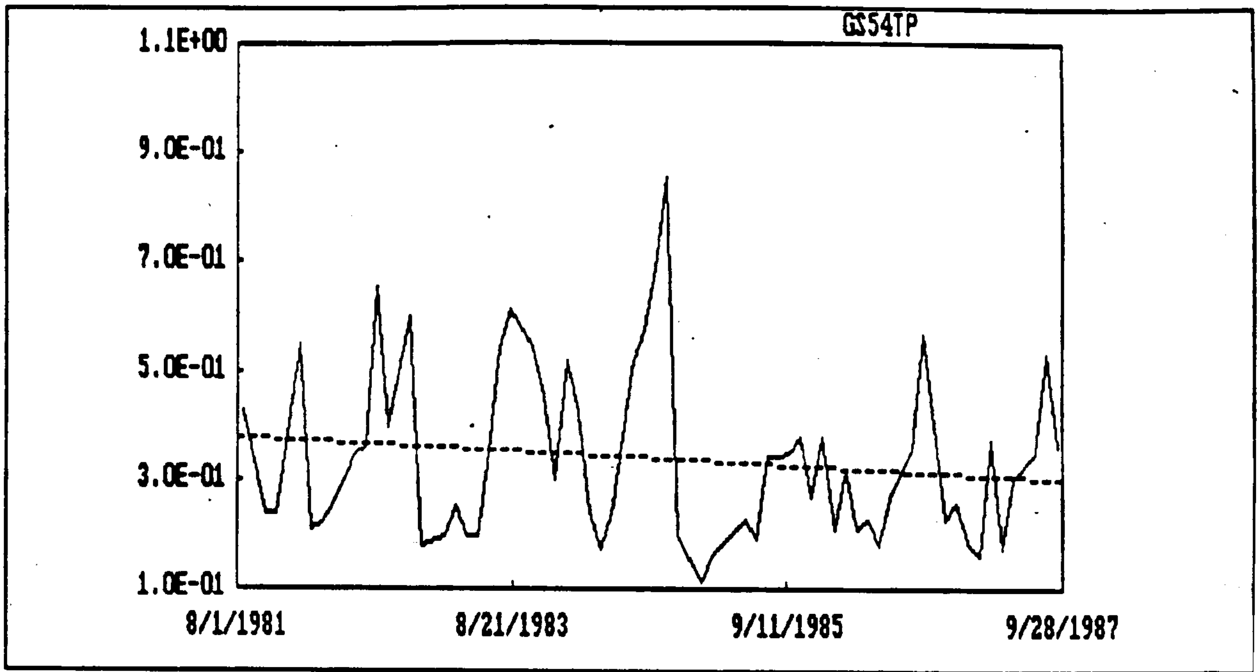

Figure B-3. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at USGS 07195400. Seasonal Kendall Sen Slope Estimate = -0.01333 mg/l/yr.

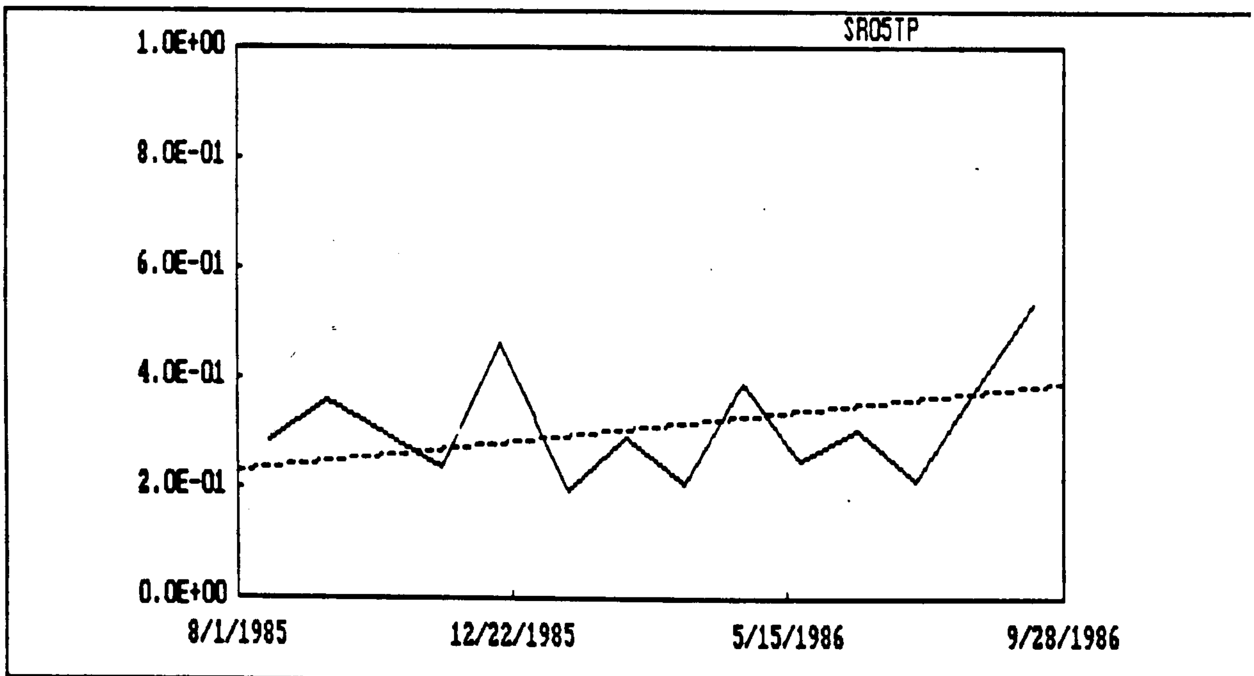

Figure B-4. Total phosphorus (as P) time series plot o monthly average concentration in mg/l at SR 0.5 Seasonal Kendall Sen Slope Estimate = 0.13 mg/l/yr.

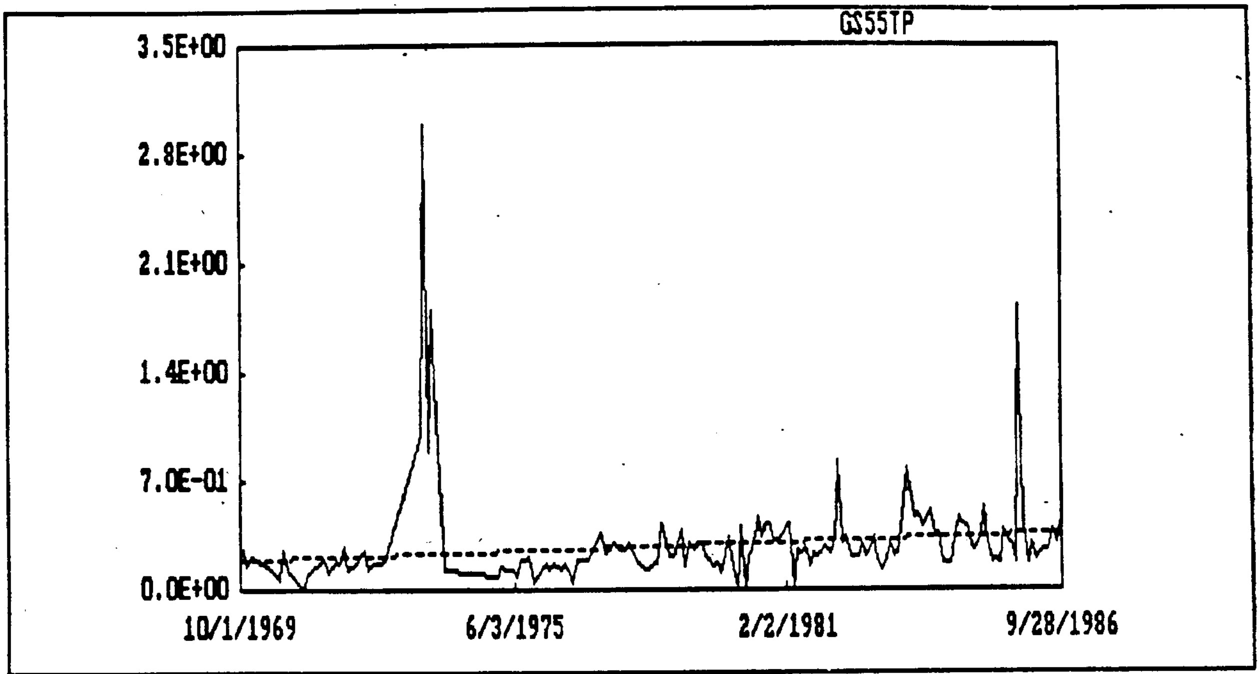

Figure B-5. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at USGS 07195500. Seasonal Kendall Sen Slope Estimate = 0.010 mg/l/yr.

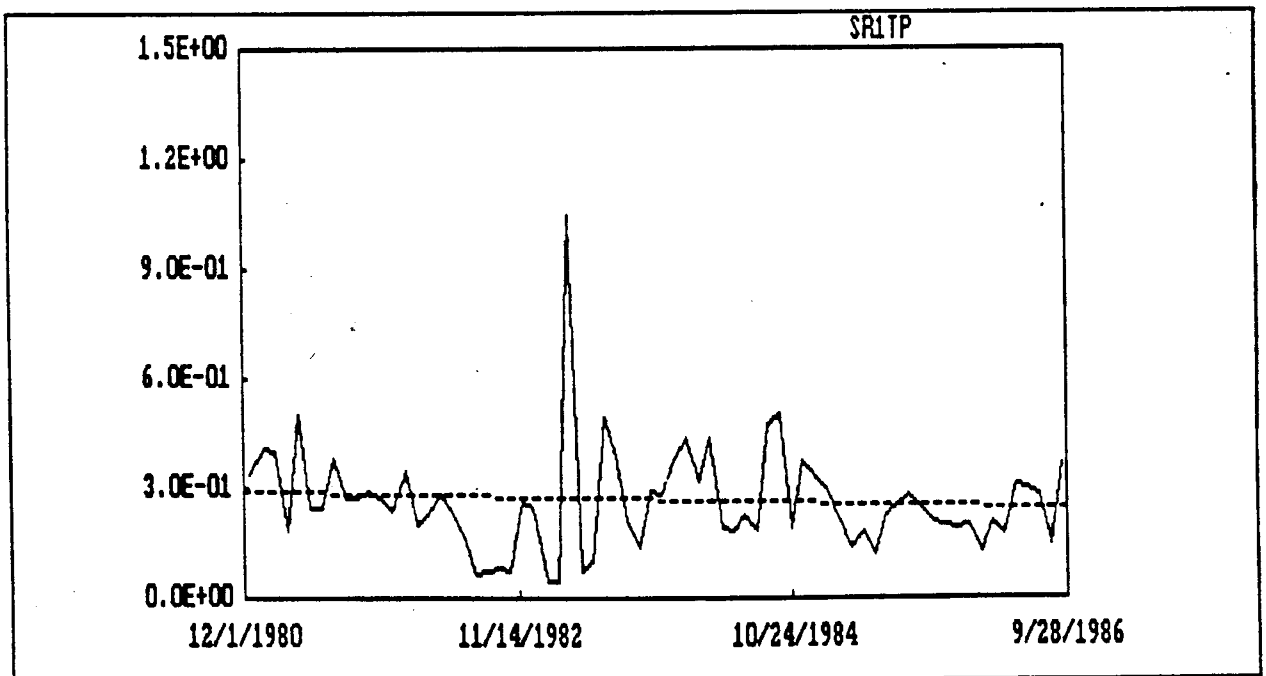

Figure B-6. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at SR 1. Seasonal Kendall Sen Slope Estimate = -0.008 mg/l/yr.

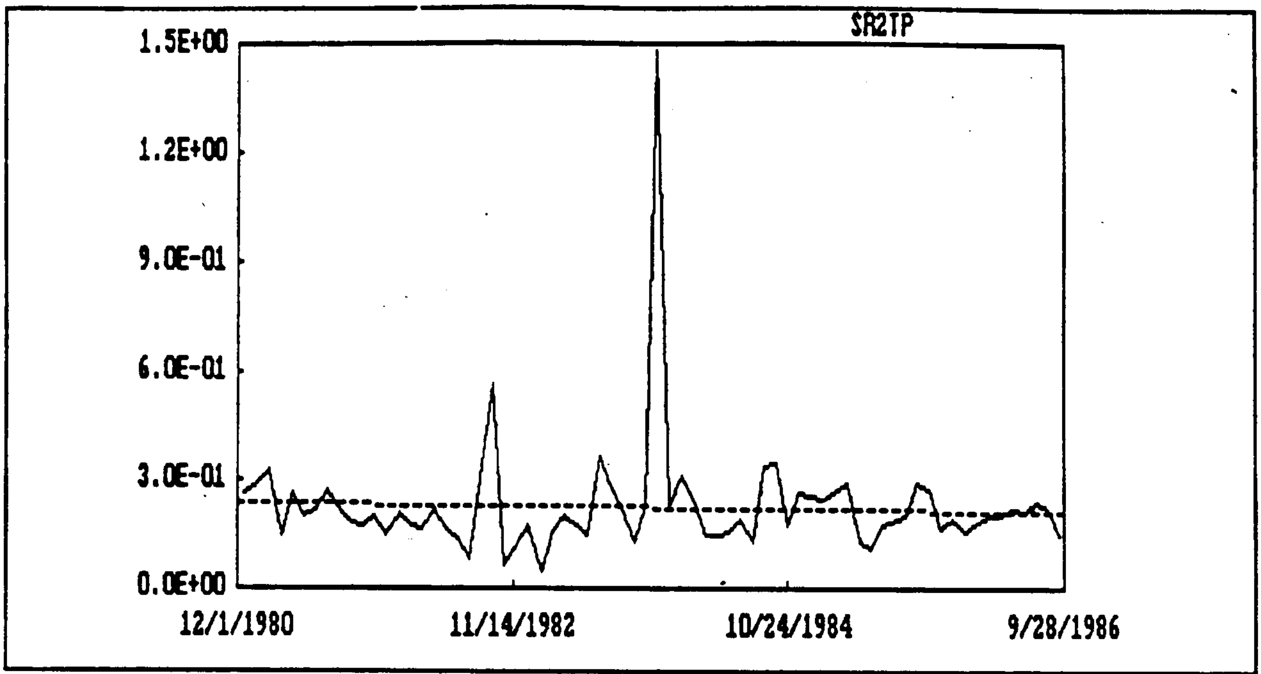

Figure B-7: Total phosphorus (as P) time series plot of monthly average concentration in mg/l at SR 2. Seasonal Kendall Sen Slope Estimate = -0.004 mg/l/yr.

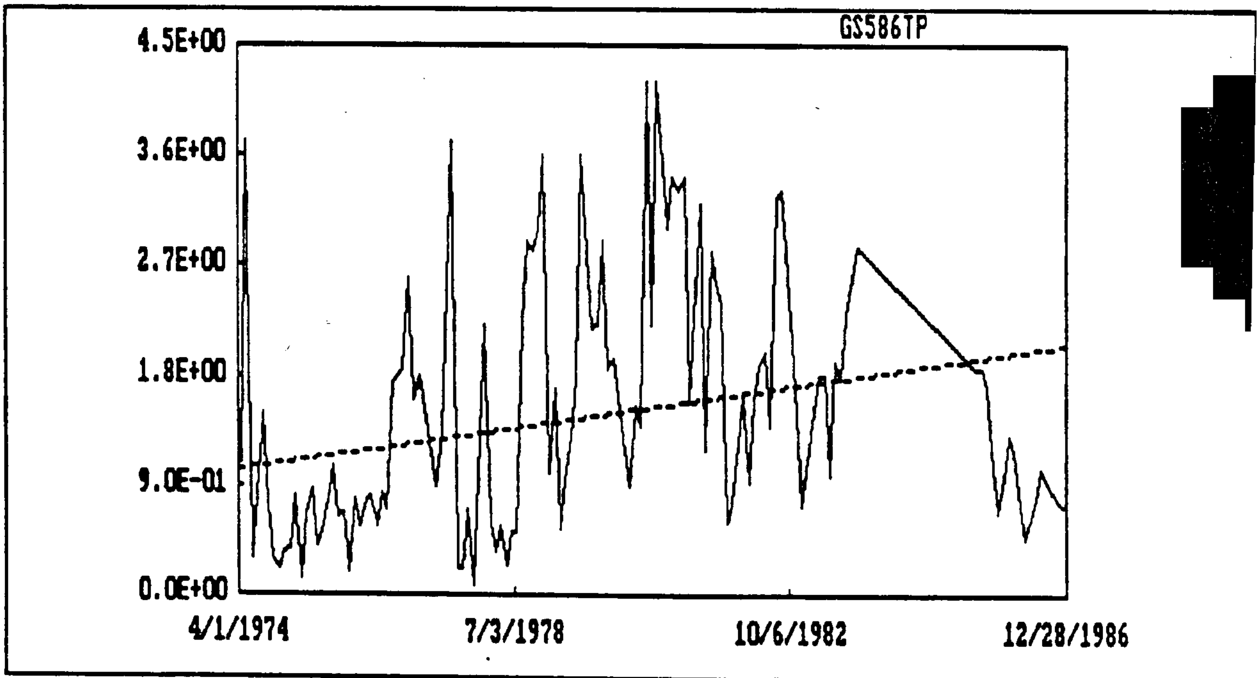

Figure B-8. Total phosphorus (as P) time series plot o: monthly average concentration in mg/l at USG: 07195860. Seasonal Kendall Sen Slope Estimat = 0.079 mg/l/yr.

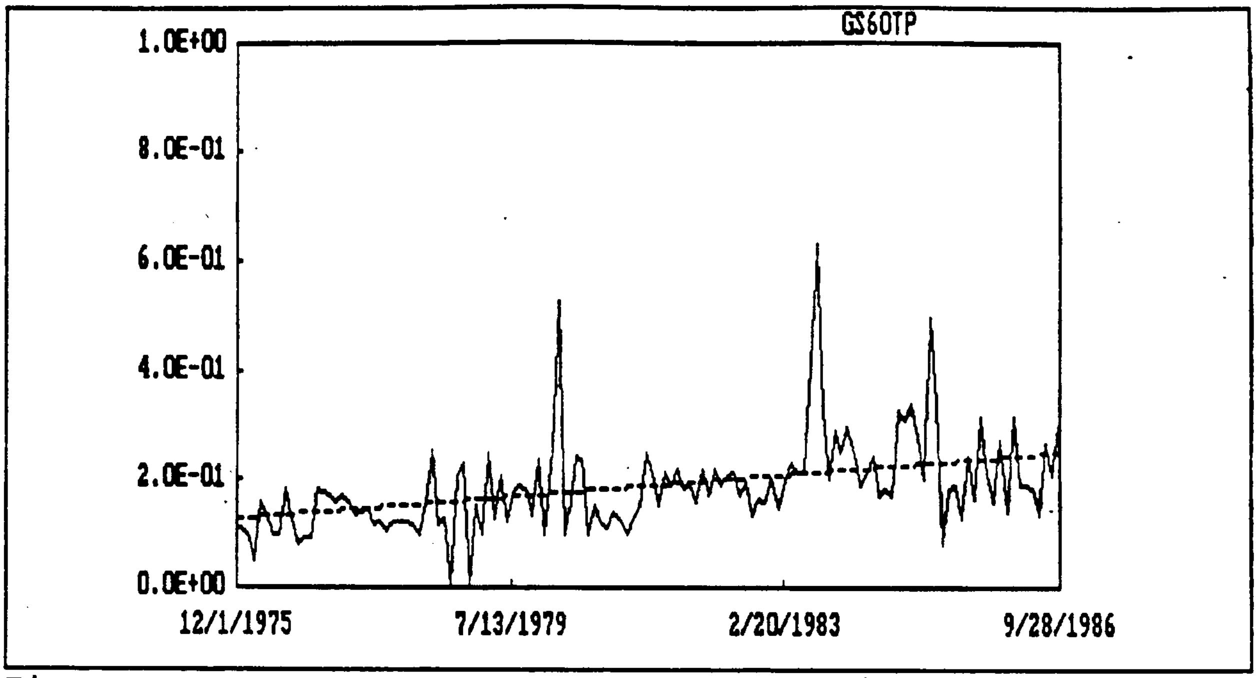

Figure B-9. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at USGS 07196000. Seasonal Kendall Sen Slope Estimate = 0.011 mg/l/yr.

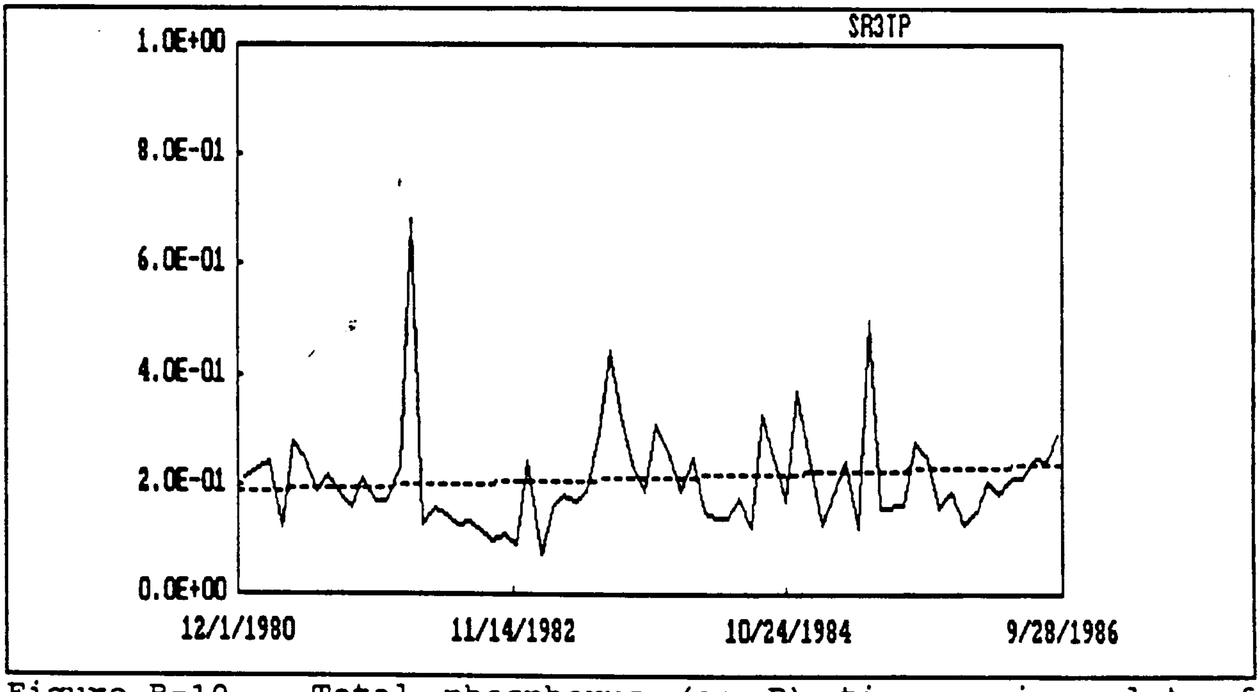

Figure B-10. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at SR 3. Seasonal Kendall Sen Slope Estimate = 0.008 mg/l/yr.

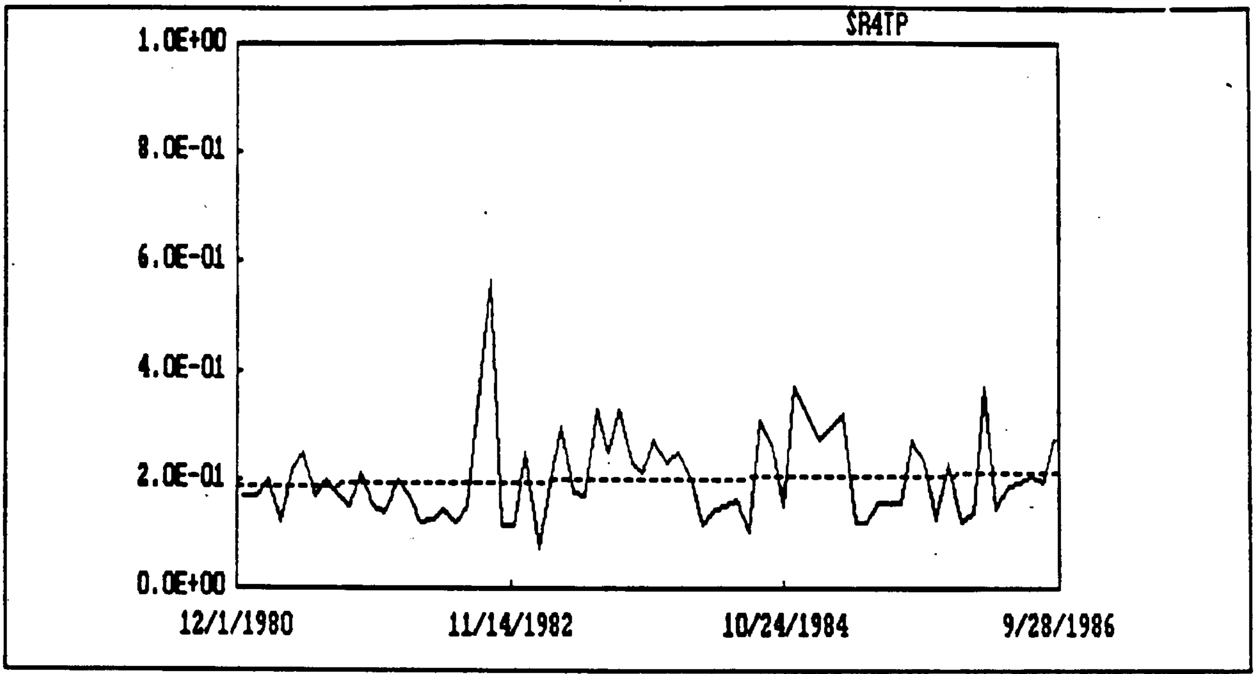

Figure B-11. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at SR 4. Seasonal Kendall Sen Slope Estimate = 0.004 mg/l/yr.

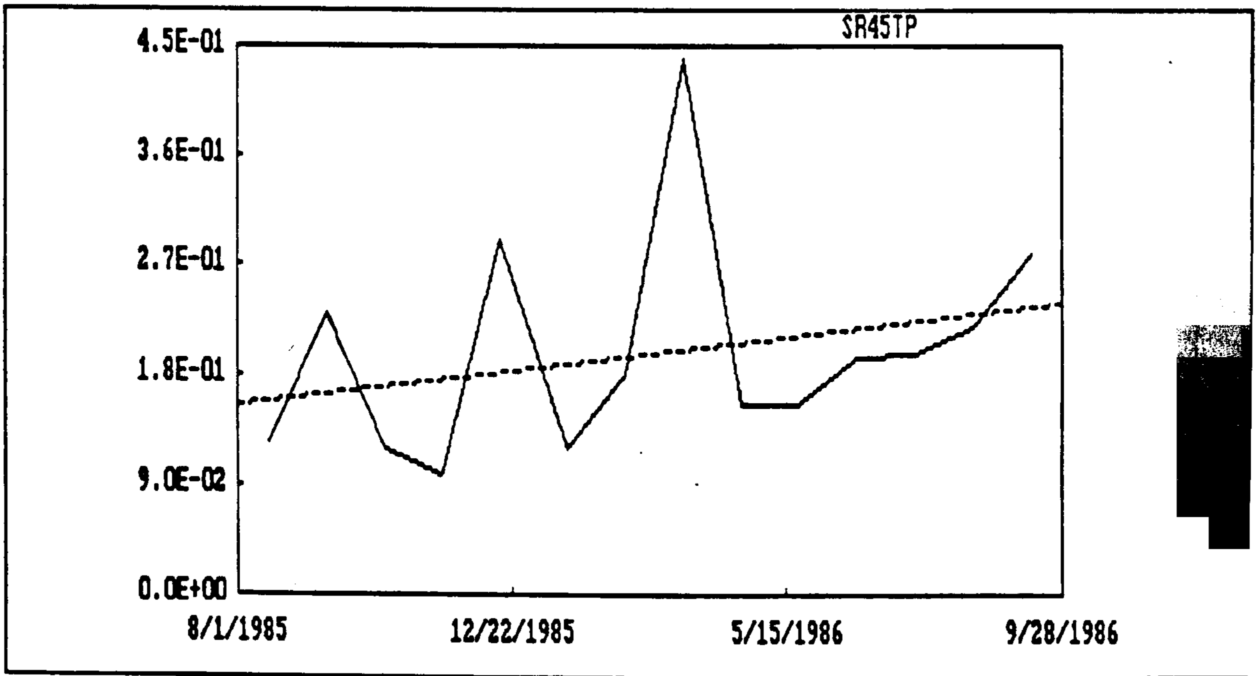

Figure B-12. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at SR 4.5. Seasonal Kendall Sen Slope Estimate = 0.07(mg/l/yr.

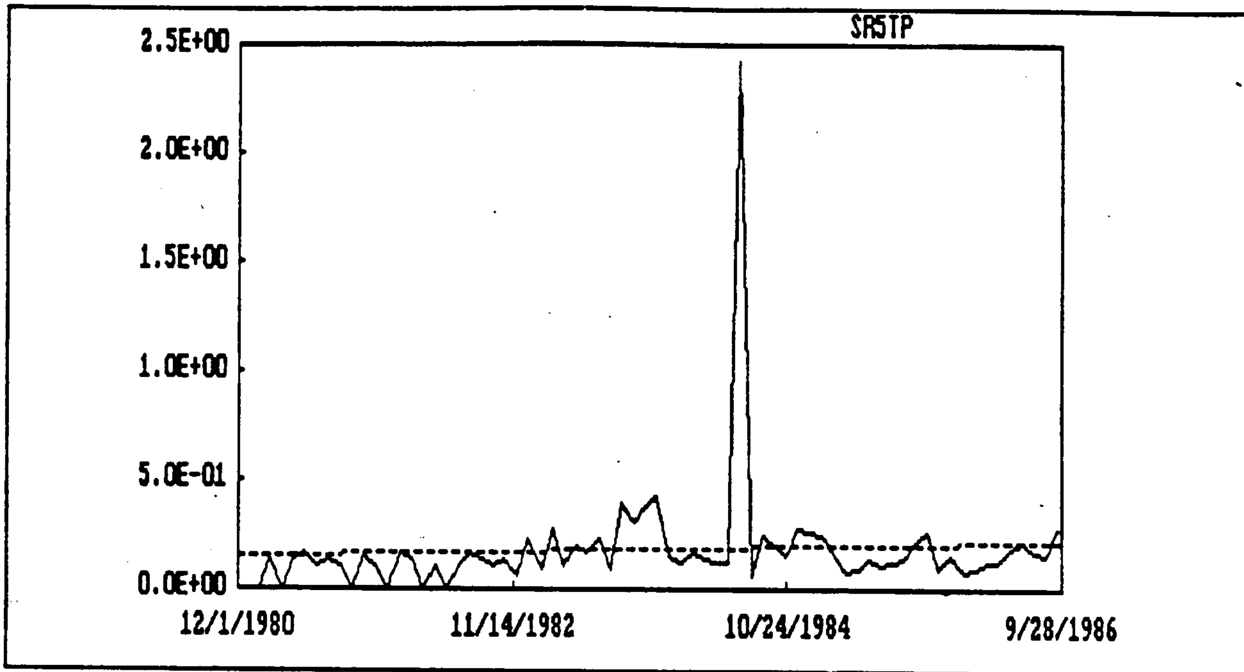

Figure B-13. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at SR 5. Seasonal Kendall Sen Slope Estimate = 0.009 mg/l/yr.

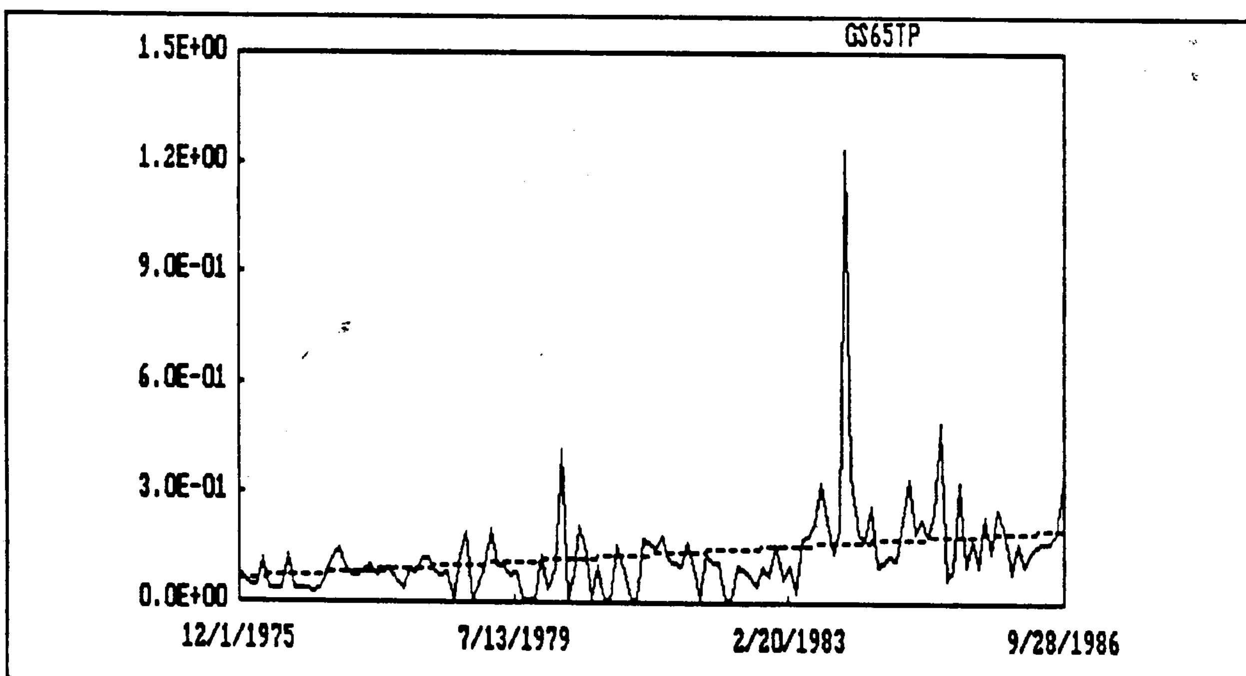

Figure B-14. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at USGS 07196500. Seasonal Kendall Sen Slope Estimate = 0.012 mg/l/yr.

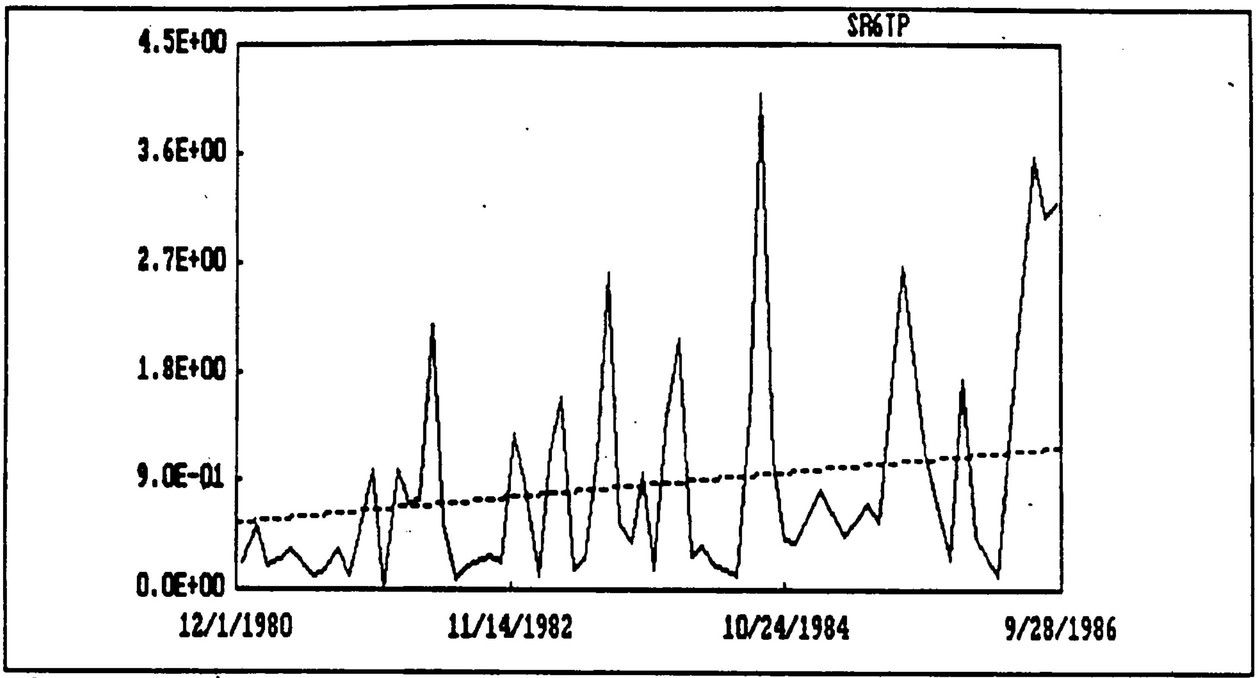

Figure B-15. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at SR 6. Seasonal Kendall Sen Slope Estimate = 0.104 mg/l/yr.

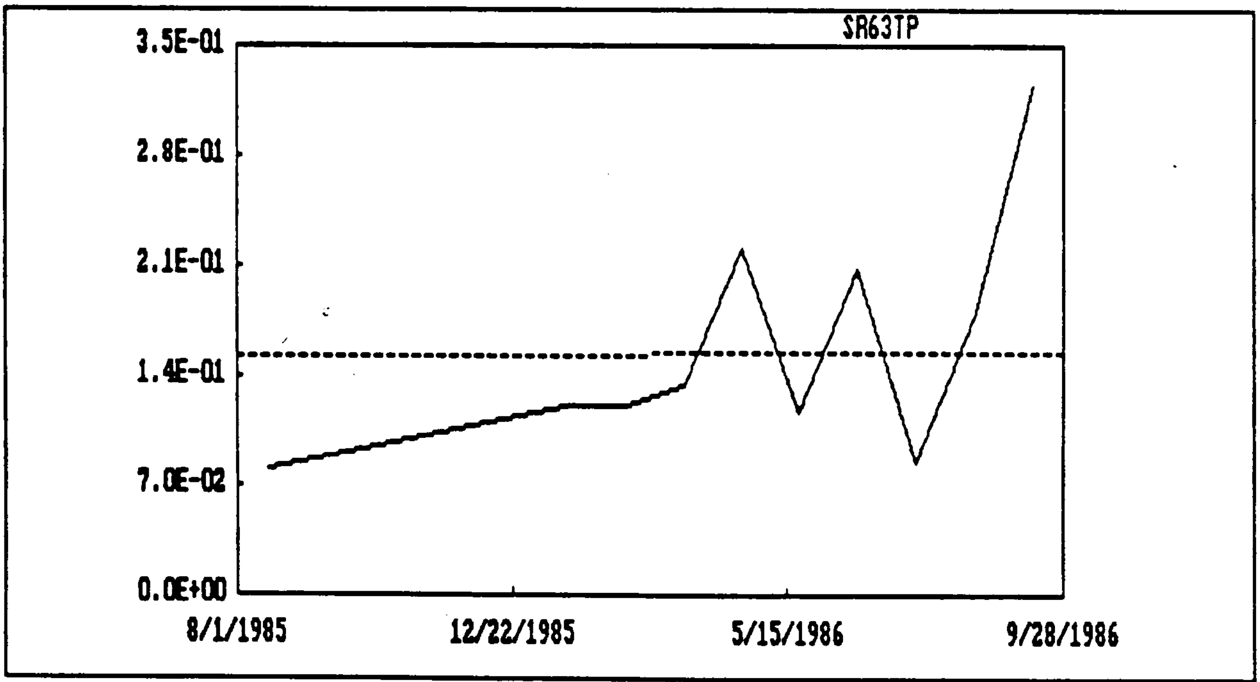

Figure B-16. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at SR 6.3. Seasonal Kendall Sen Slope Estimate = 0.001 mg/l/yr.

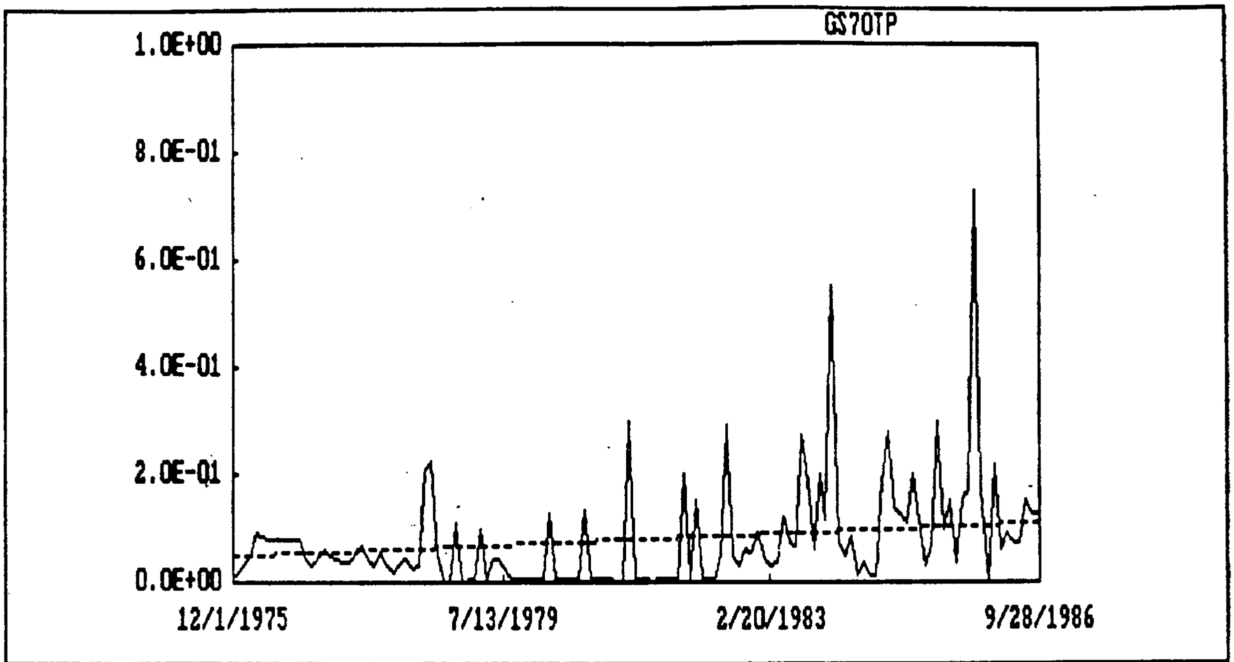

Figure B-17. Total phosphorus (as P) time series plot of monthly average concentration in mg/l at USGS 07197000. Seasonal Kendall Sen Slope Estimate = 0.005 mg/l/yr.

APPENDIX C

COMPARISON OF MEDIAN TOTAL PHOSPHATE CONCENTRATION OF UPSTREAM VS DOWNSTREAM STATIONS

LIST OF FIGURES

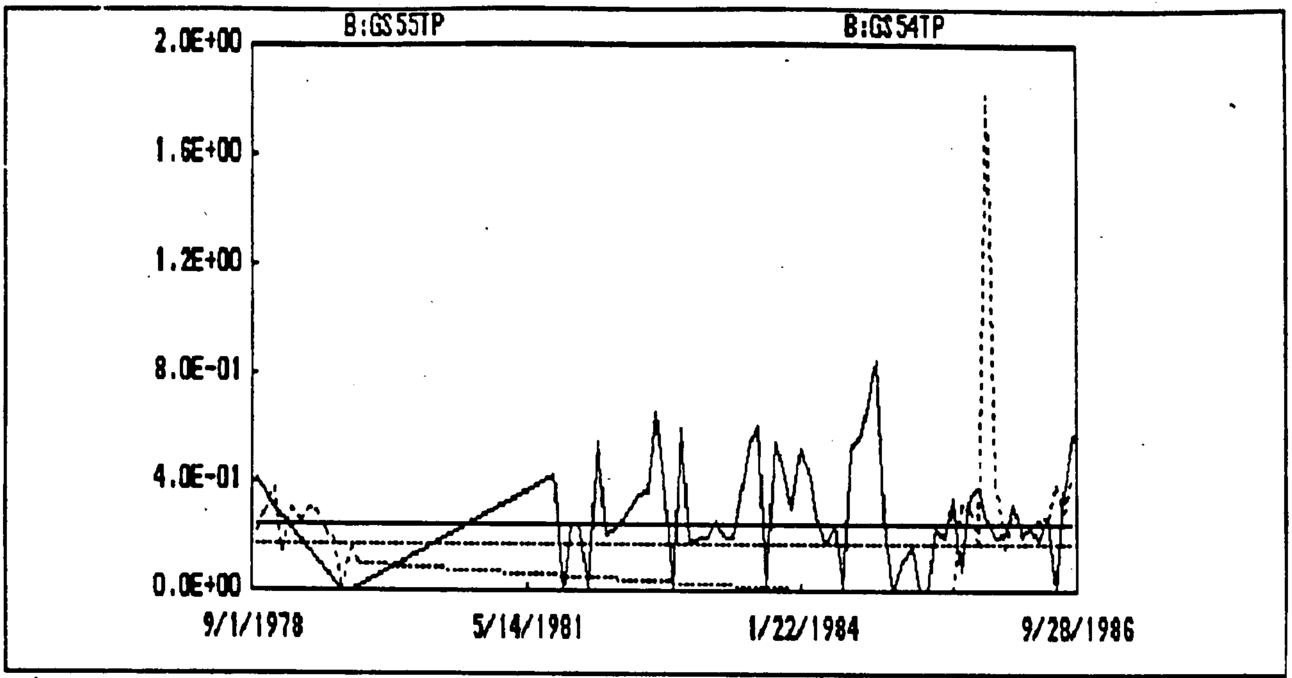

Figure C-1. Comparison of median total phosphate (P) concentration at USGS 54 (solid) vs USGS 55 (dashed).

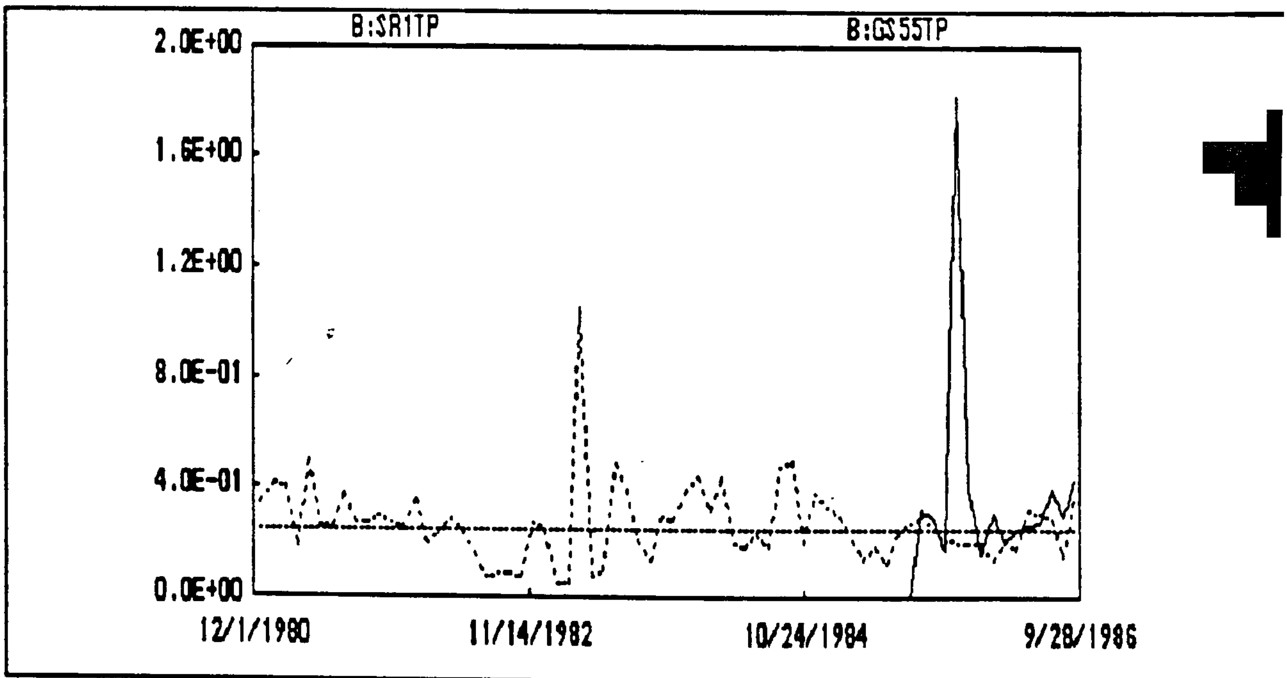

Figure C-2. Comparison of median total phosphate (P concentration (mg/l) of USGS 55 (solid) vs SR (dashed).

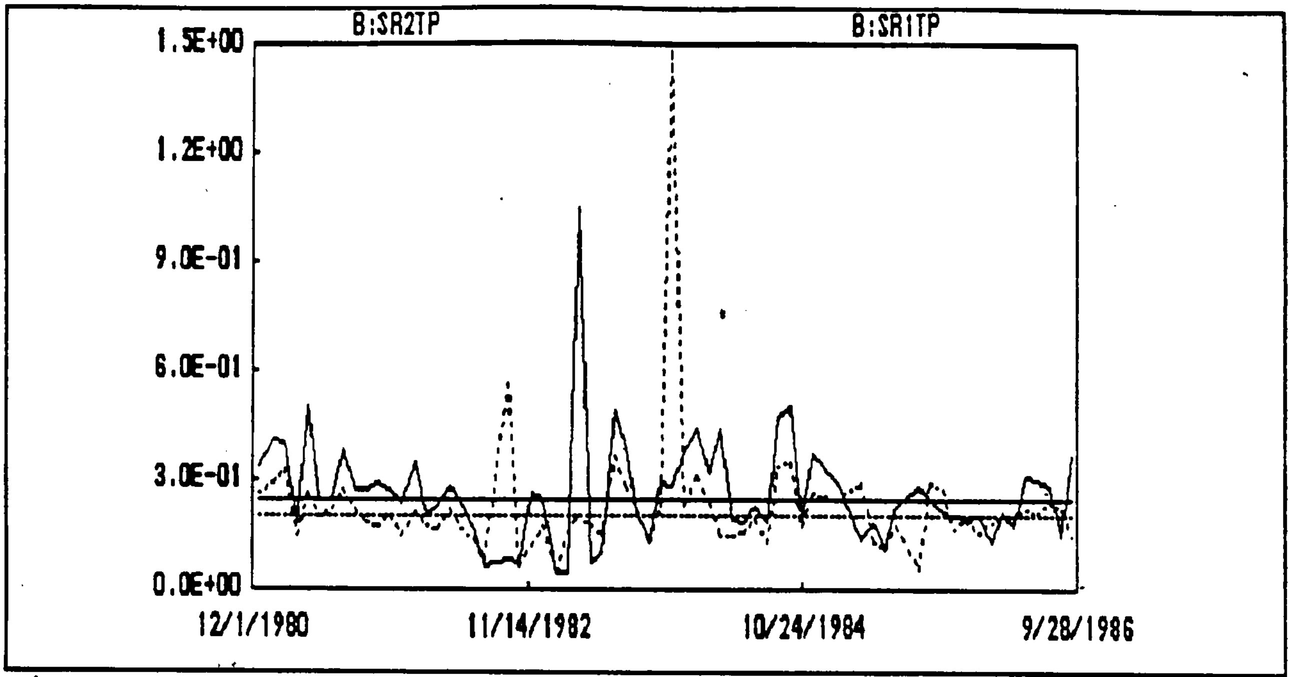

Figure C-3. Comparison of median total phosphate (P) mg/l at SR1 (solid) vs SR2 (dashed).

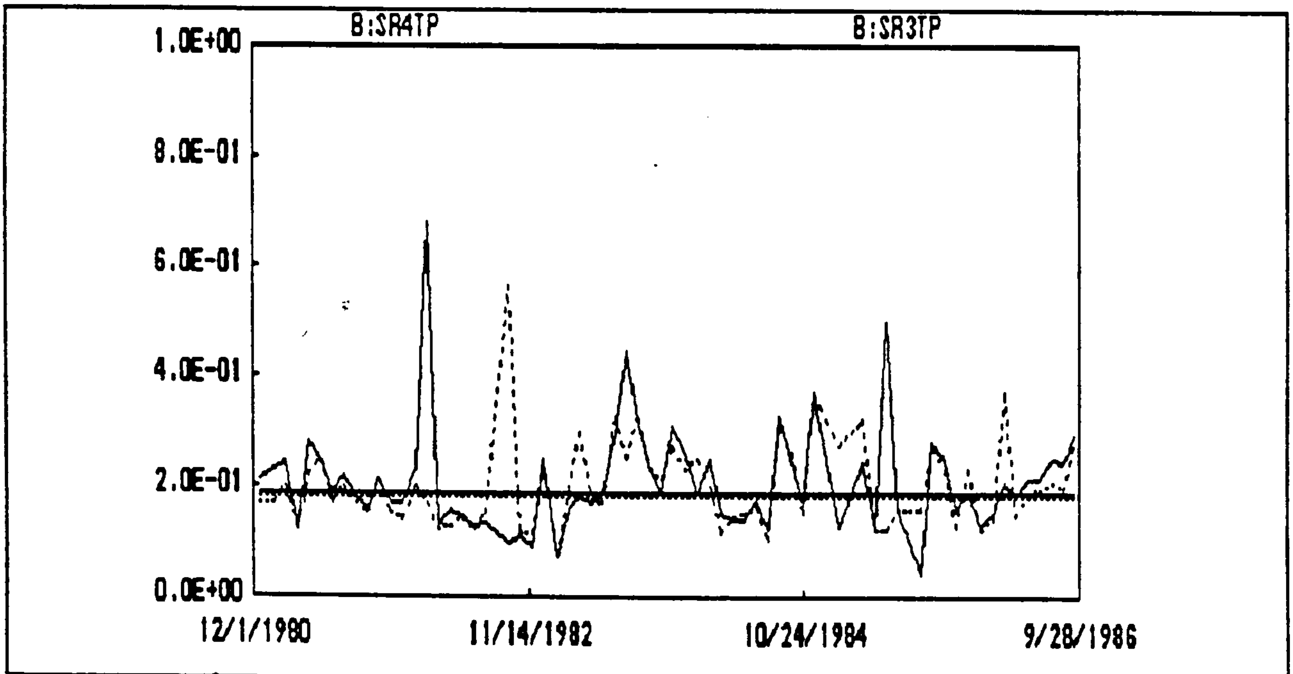

Figure C-4. Comparison of median total phosphate (P) mg/l at SR 3 (solid) vs SR 4 (dashed).

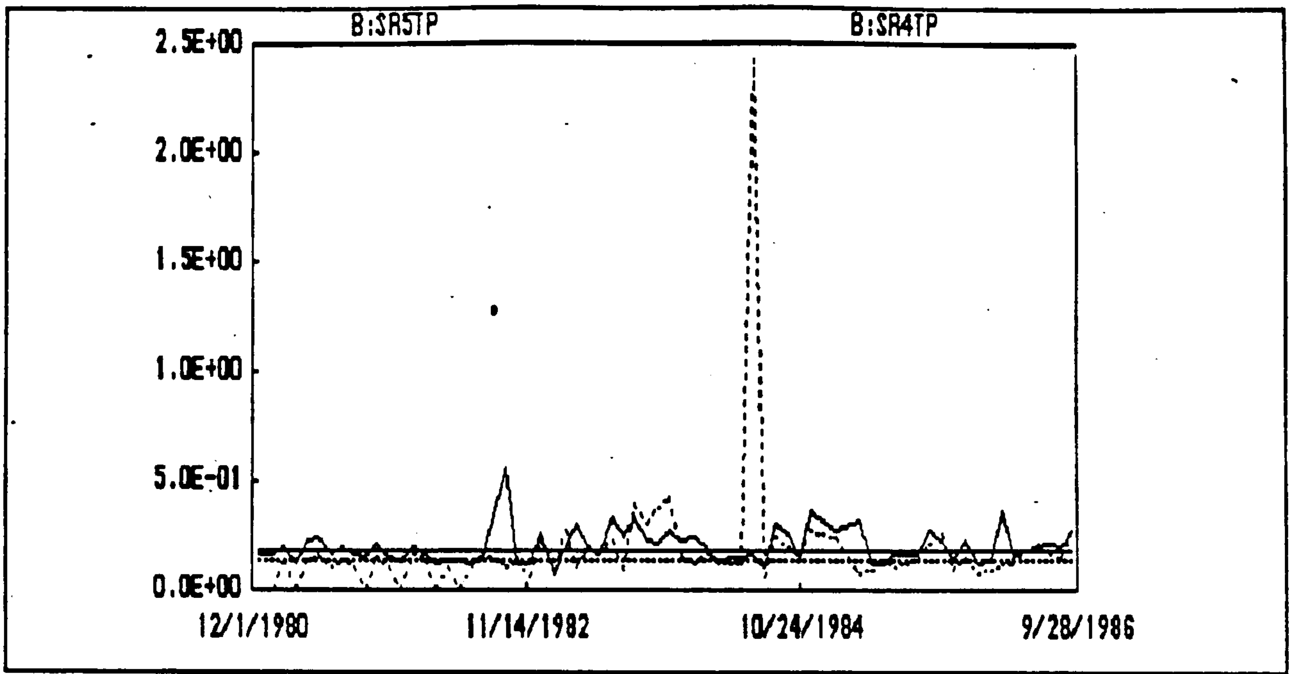

Figure C-5. Comparison of median total phosphate (P) concentration (mg/l) of SR 4 (solid) versus SR 5 (dashed).

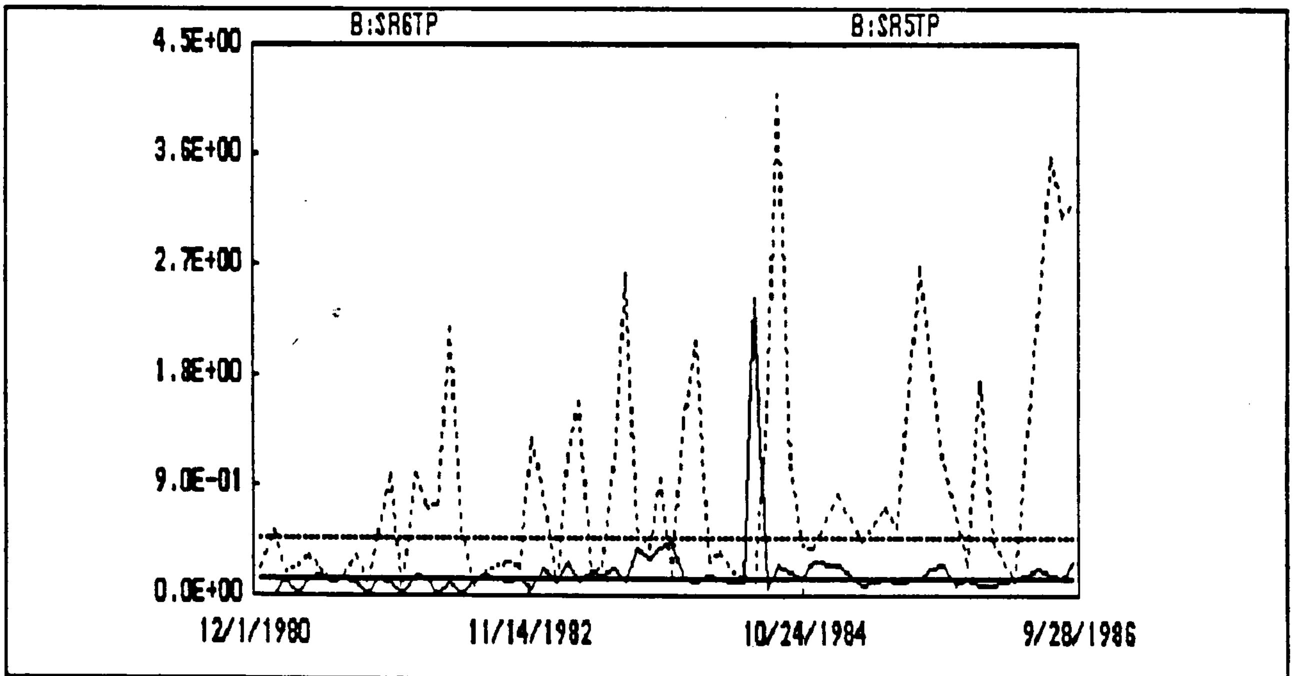

Figure C-6. Comparison of median total phosphate (P) concentration (mg/l) at SR 5 (solid) versus SR 6 (dashed).

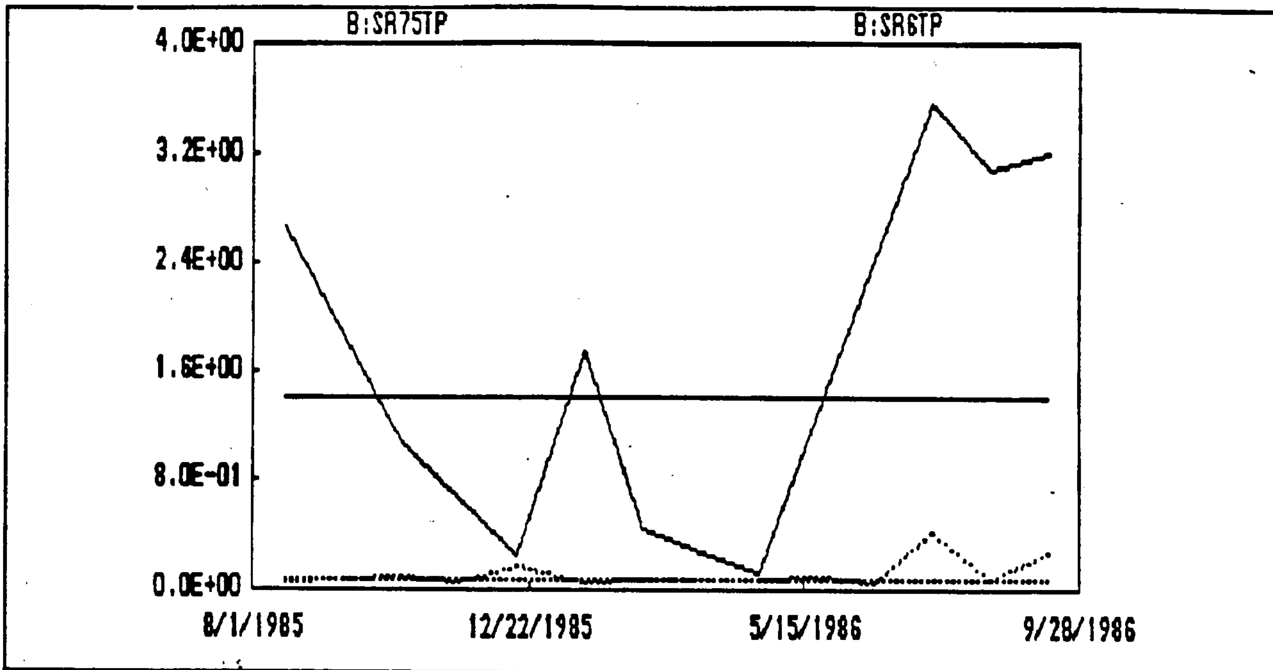

Figure C-7. Comparison of median total phosphate (P) concentration (mg/l) at SR 6 (solid) versus SR 75 (dashed).

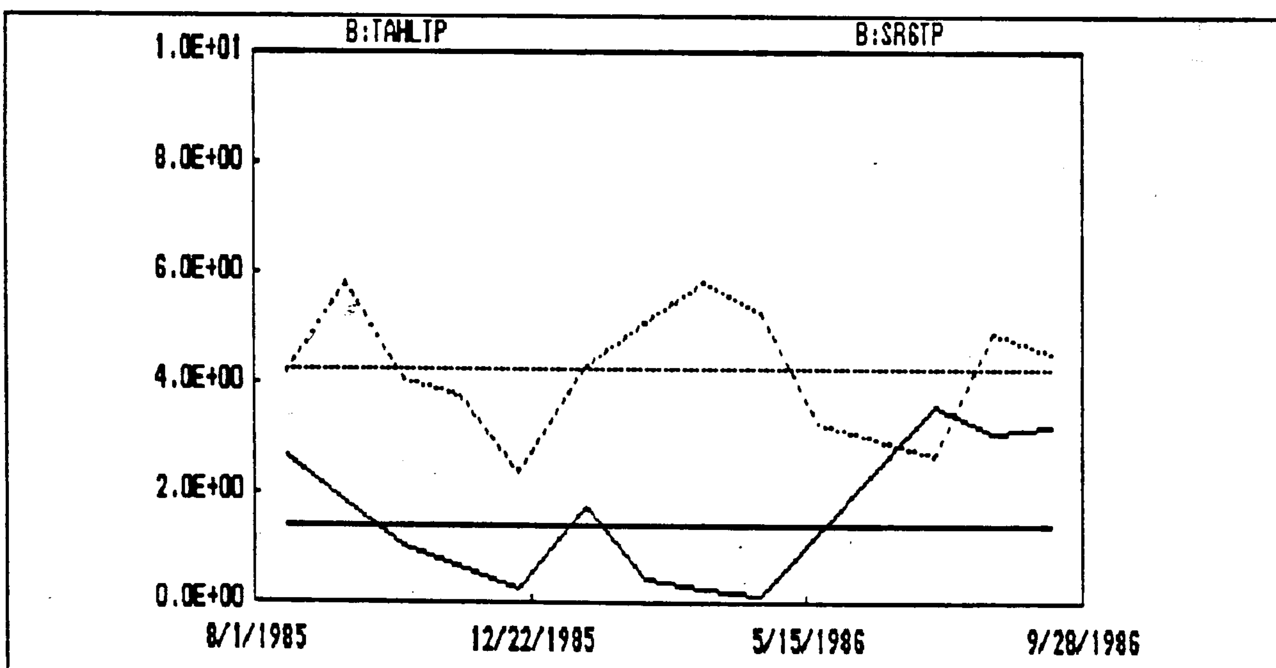

Figure C-8. Comparison of median total phosphate (P) concentration (mg/l) at SR 6 (solid) versus Tahlequah POTW (dashed).

APPENDIX D

GRAPHIC ILLUSTRATION OF LONGTERM TEMPORAL TREND OF ORTHOPHOSPHATE CONCENTRATION IN ILLINOIS RIVER

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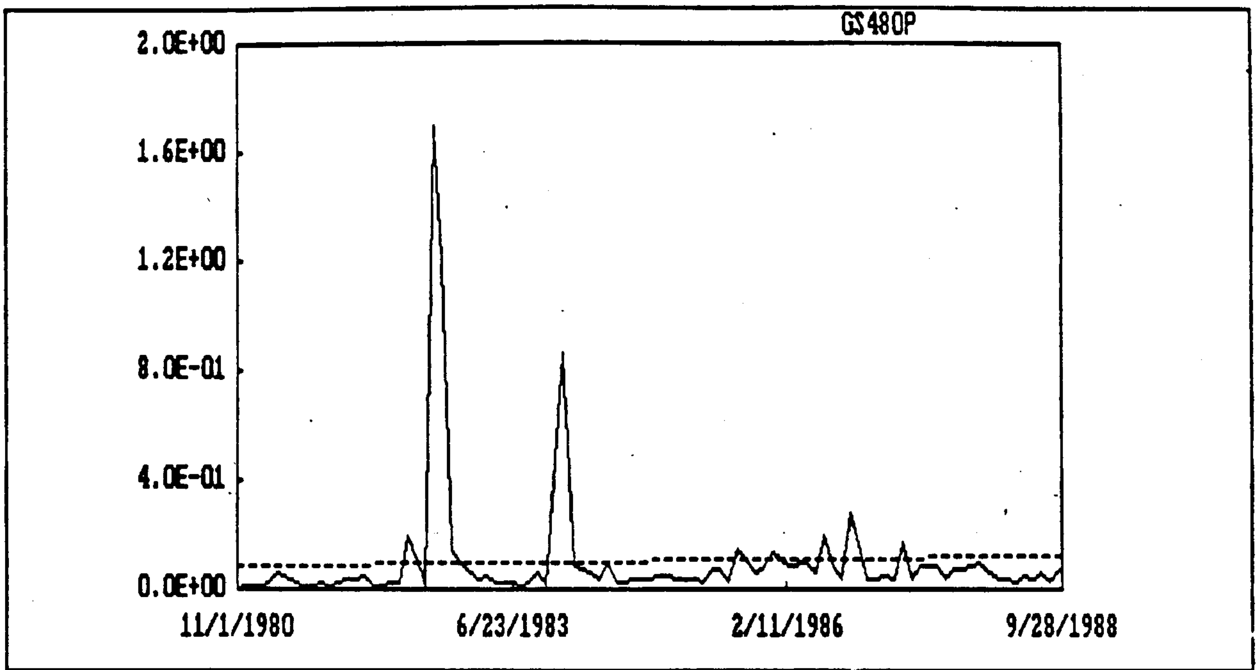

Figure D-1. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at USGS 07194800. Seasonal Kendall Sen Slope Estimate = 0.005 mg/l/yr.

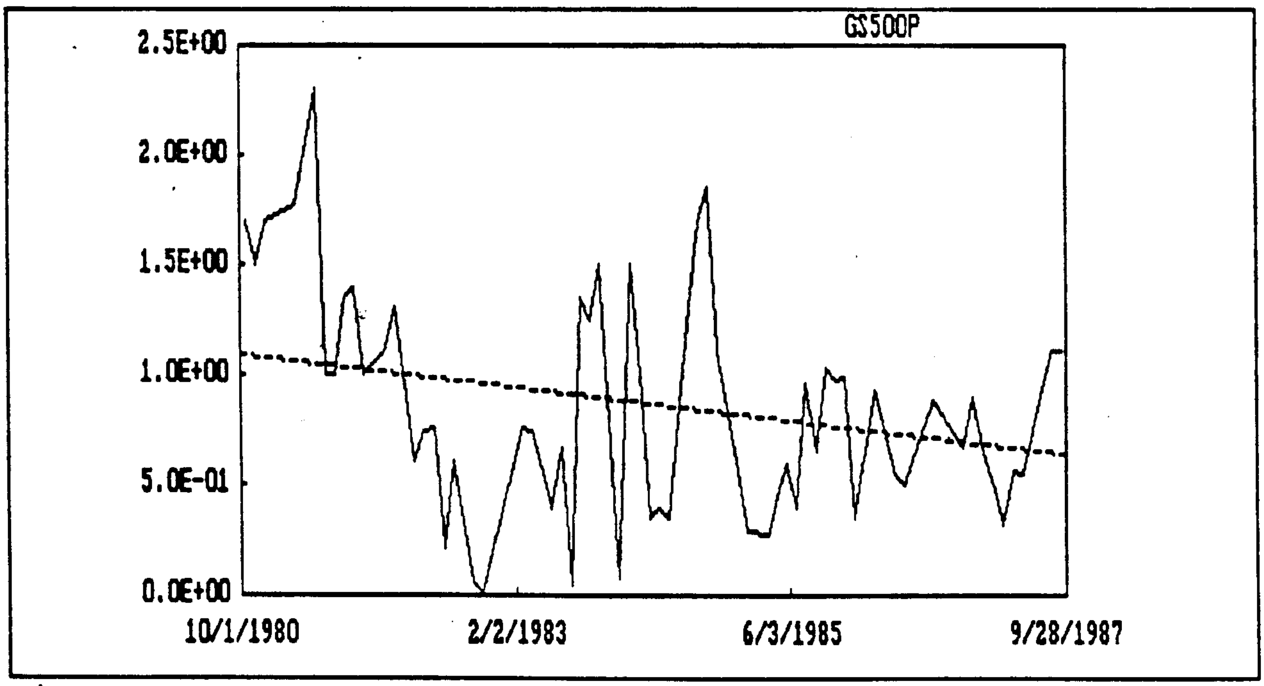

Figure D-2. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at USGS 07195000. Seasonal Kendall Sen Slope Estimate = -0.065 mg/l/yr.

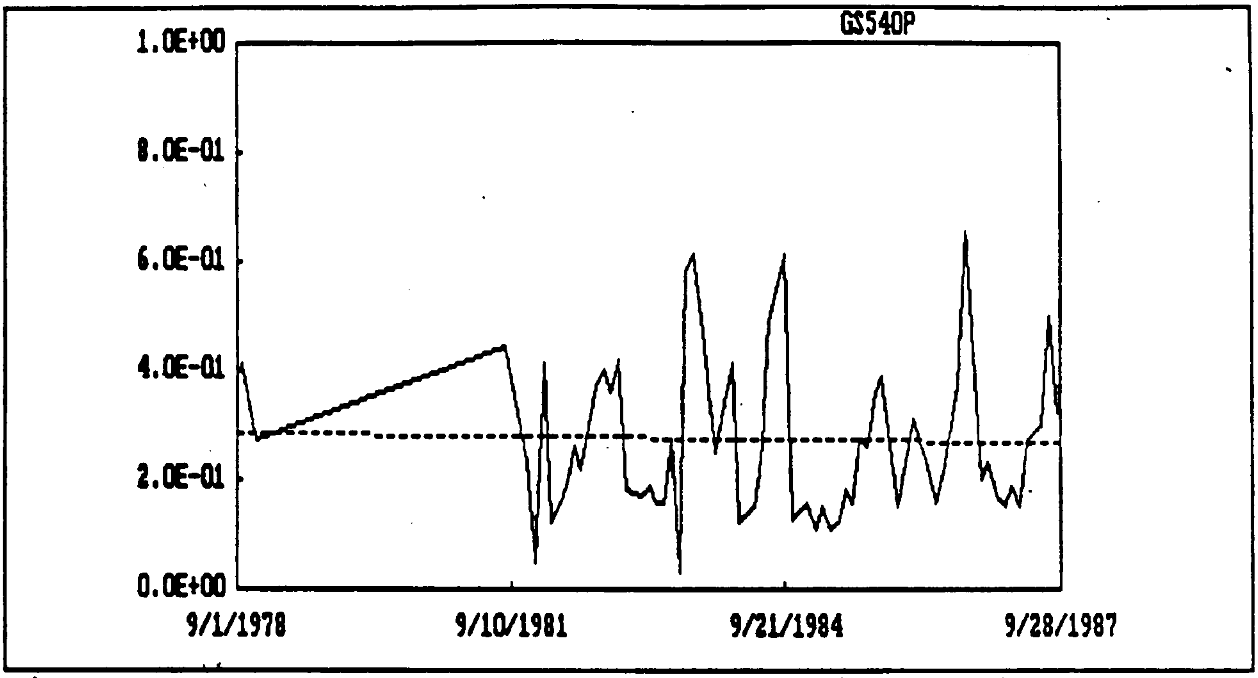

Figure D-3. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at USGS 07195400. Seasonal Kendall Sen Slope Estimate = -0.002 mg/l/yr.

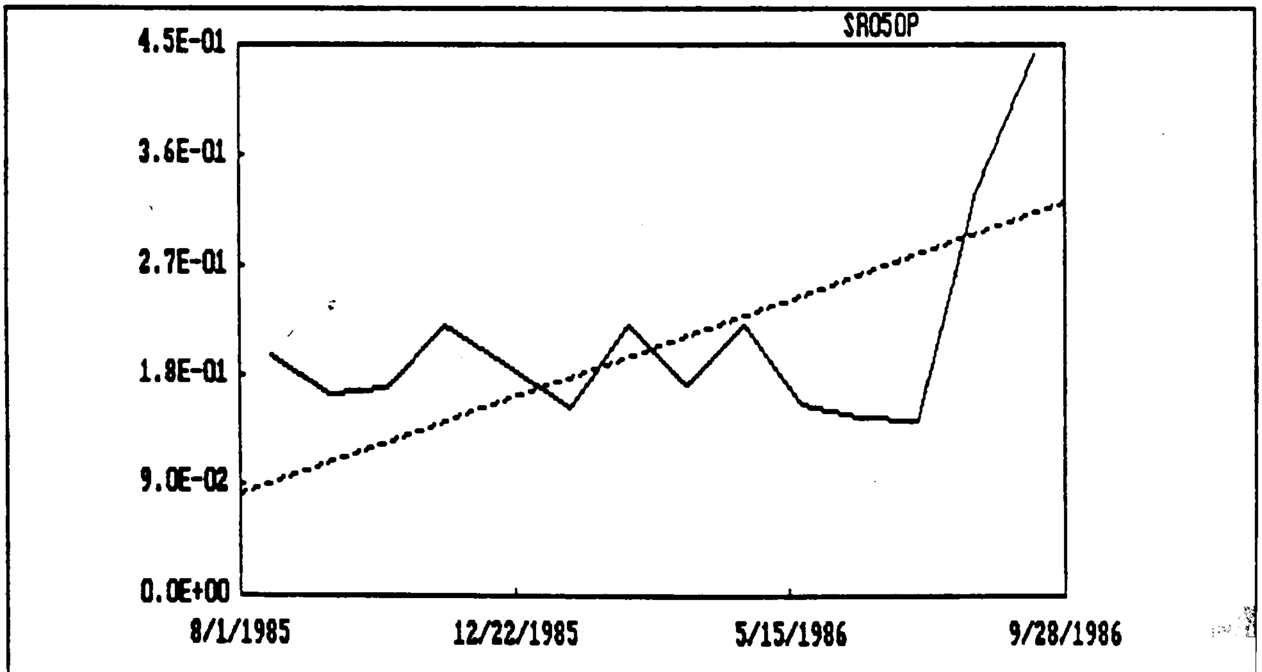

Figure D-4. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at SR 0.5. Seasonal Kendall Sen Slope Estimate = 0.205 mg/l/yr.

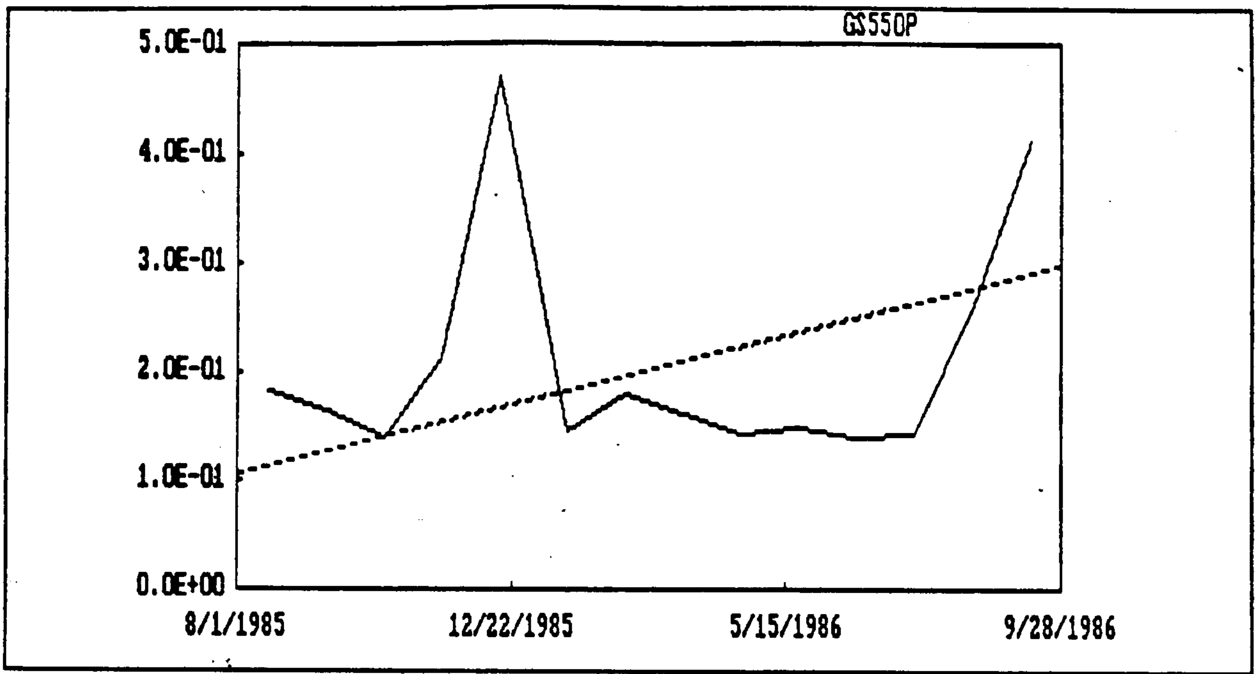

Figure D-5. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at USGS 07195500. Seasonal Kendall Sen Slope Estimate = 0.163 mg/l/yr.

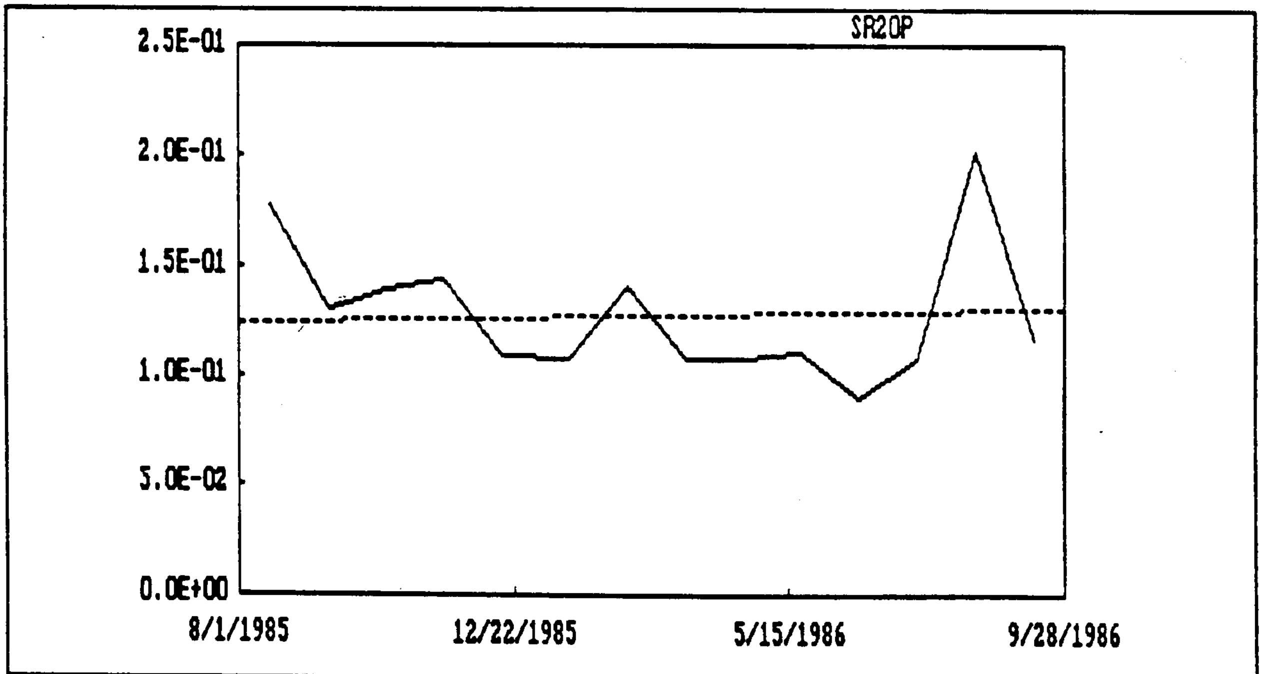

Figure D-6. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at SR 2. Seasonal Kendall Sen Slope Estimate = 0.006 mg/l/yr.

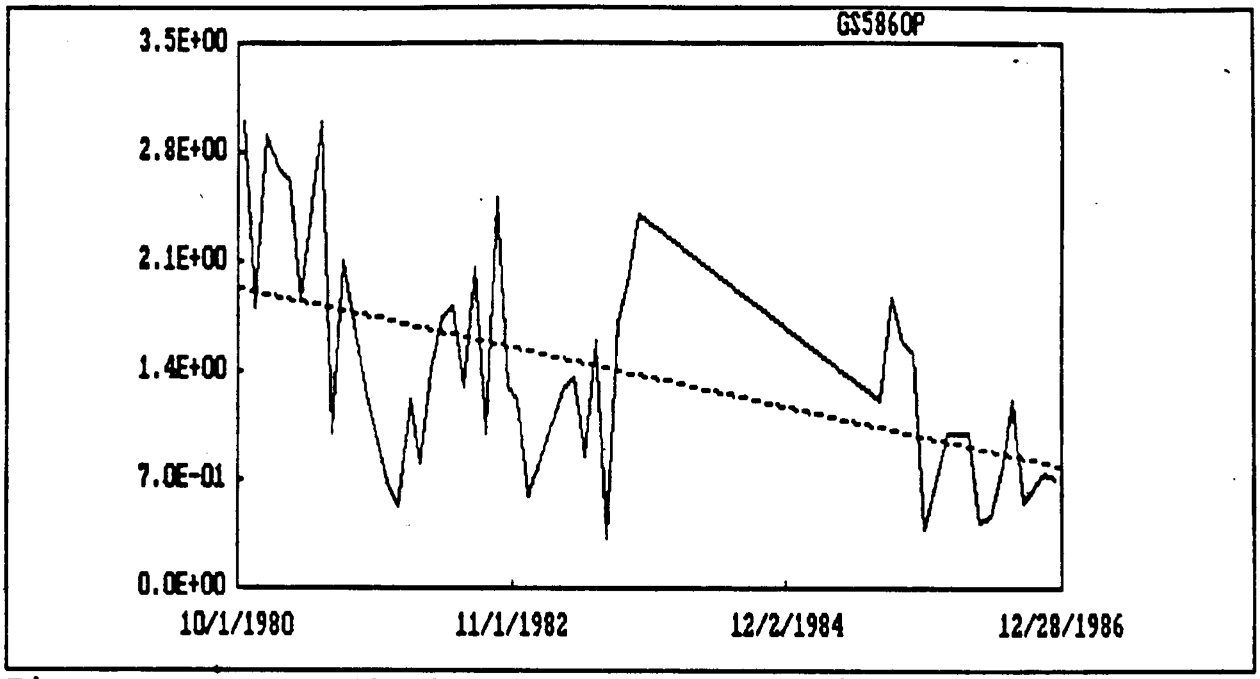

Figure D-7. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at usgs 07195860. Seasonal Kendall Sen Slope Estimate = -0.181 mg/l/yr.

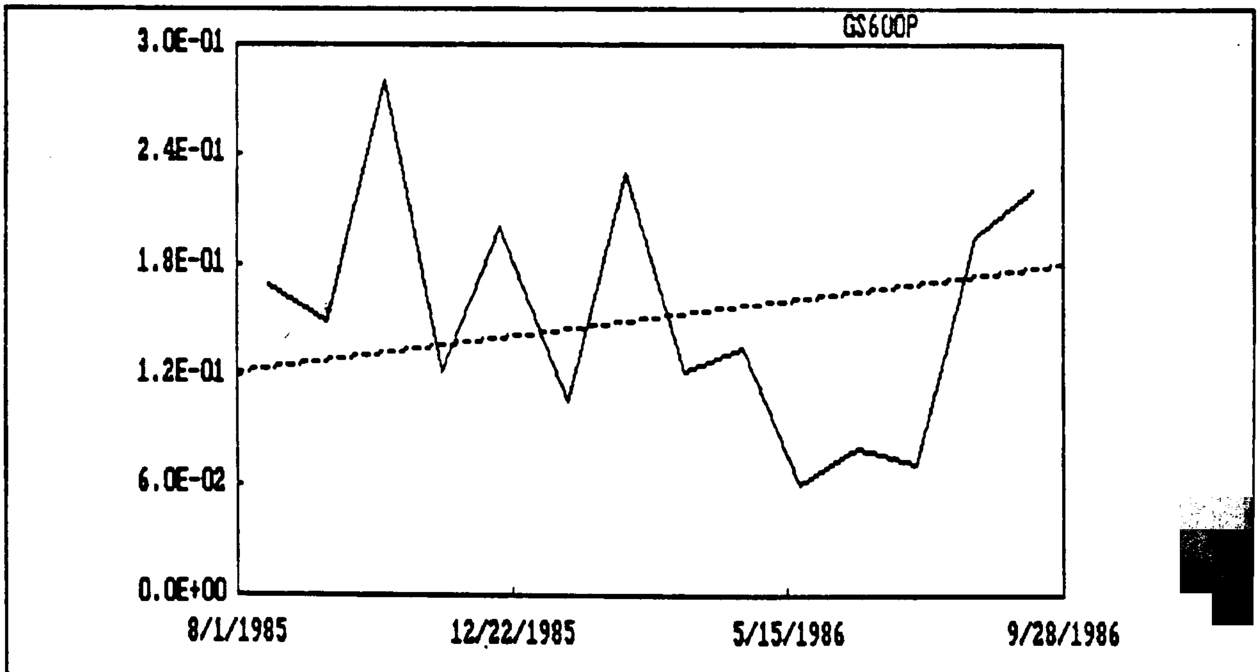

Figure D-8. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at USGS 07196000. Seasonal Kendall Sen Slope Estimate = 0.048 mg/l/yr.

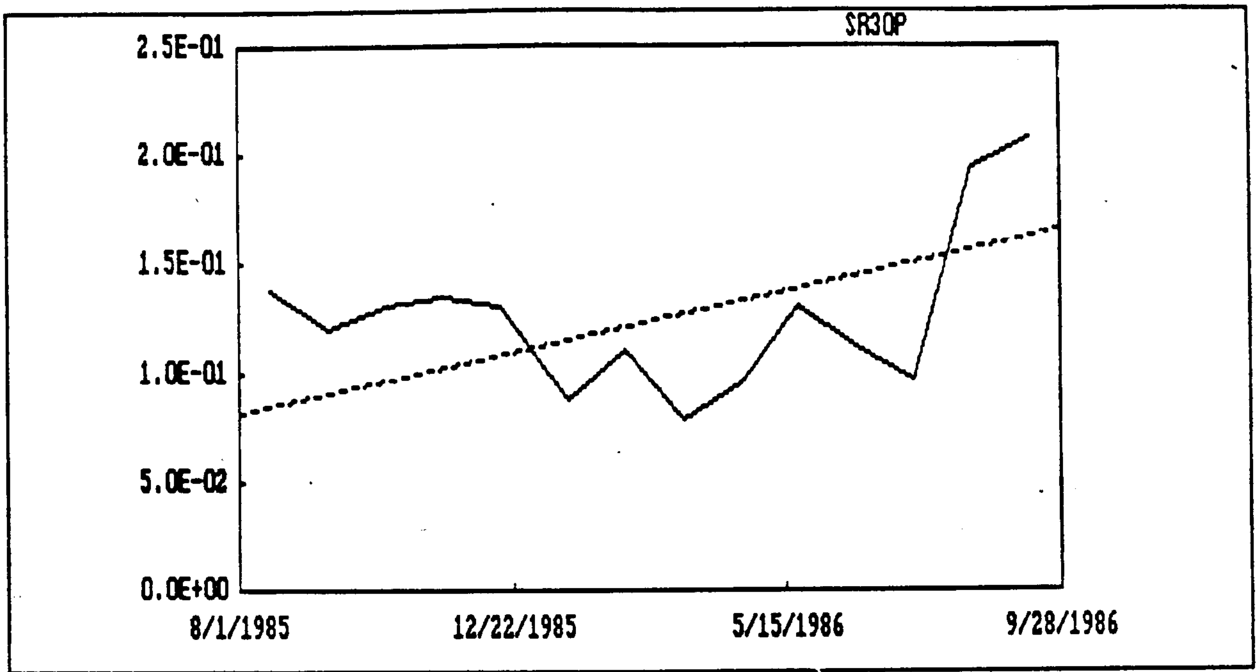

Figure D-9. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at SR 3. Seasonal Kendall Sen Slope Estimate = 0.072 mg/l/yr.

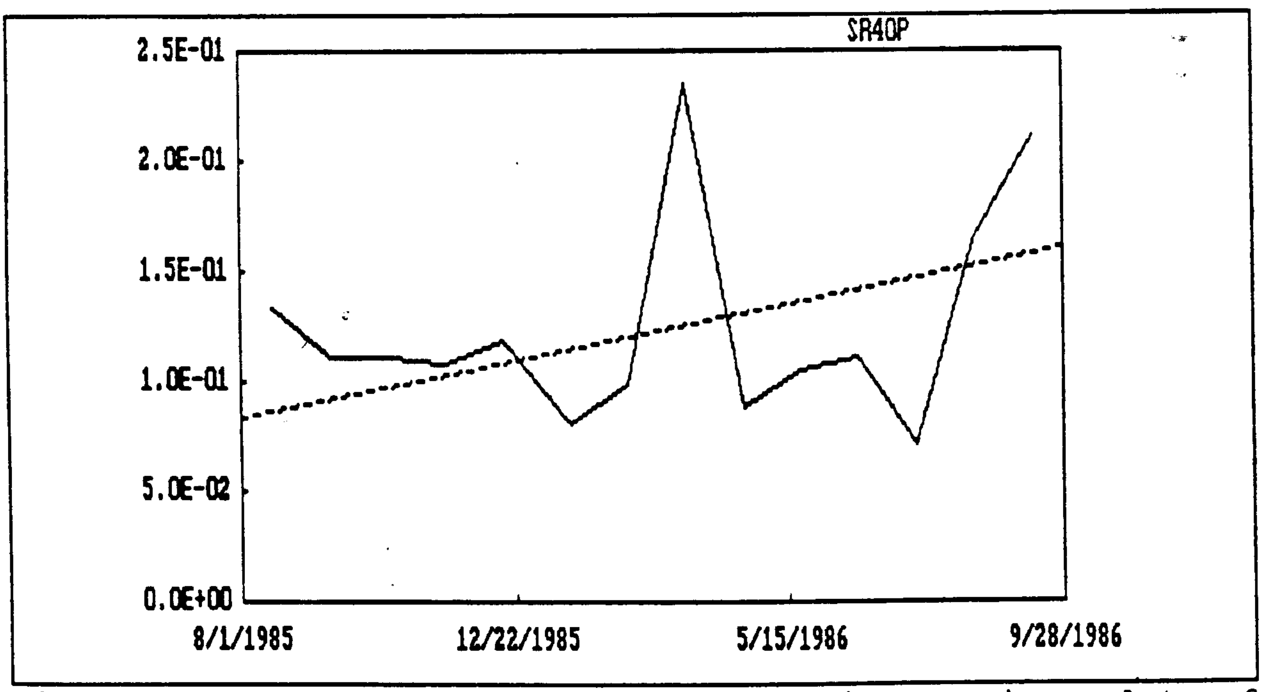

Figure D-10. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at SR 4. Seasonal Kendall Sen Slope Estimate =0.065 mg/l/yr.

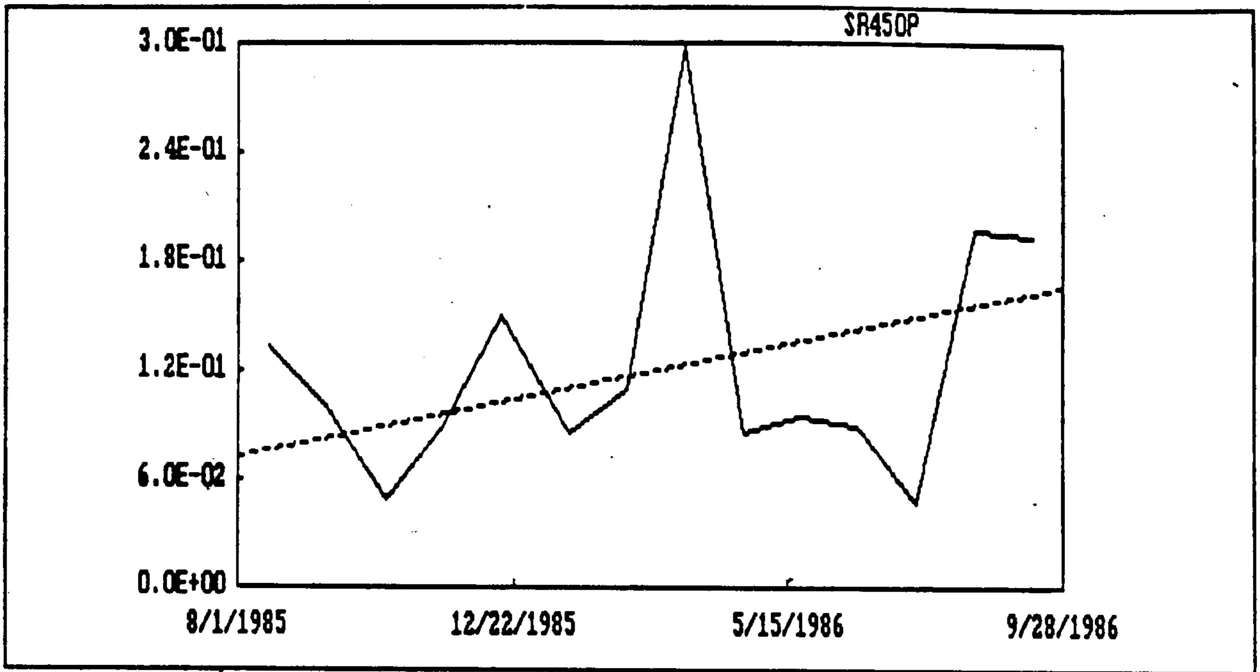

Figure D-11. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at SR 4.5. Seasonal Kendall Sen Slope Estimate = 0.080 mg/l/yr.

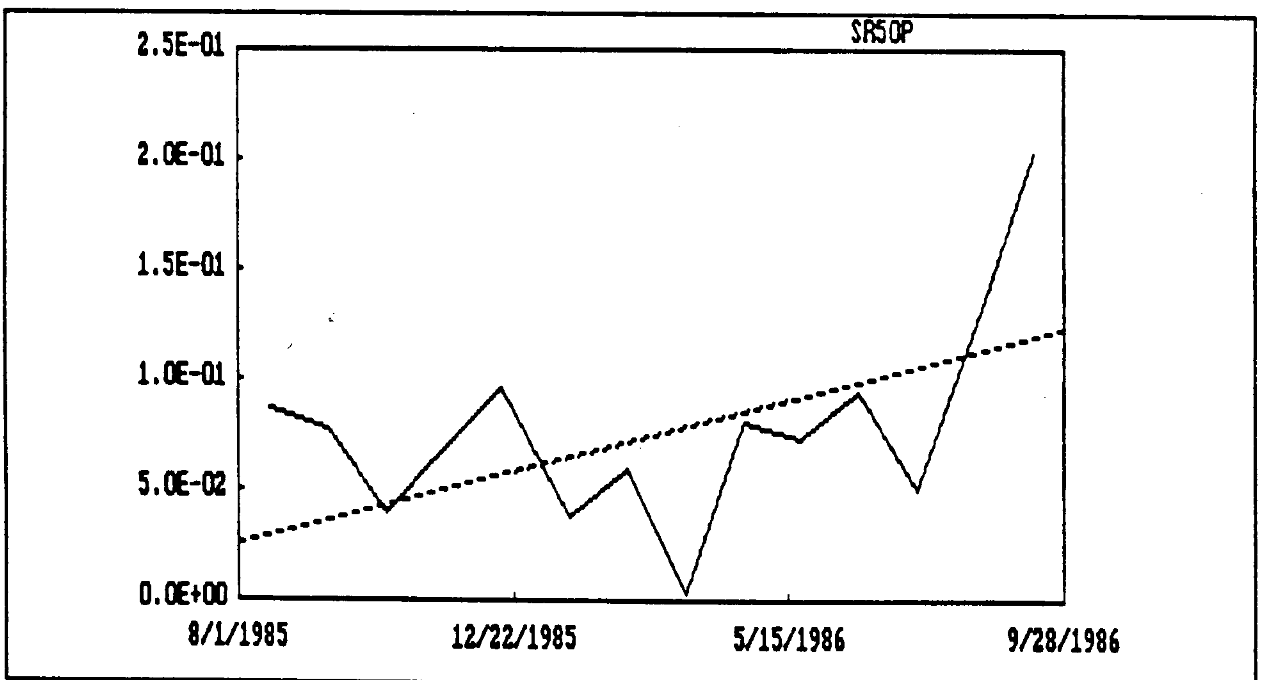

Figure D-12. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at SR 5. Seasonal Kendall Sen Slope Estimate = 0.082 mg/l/yr.

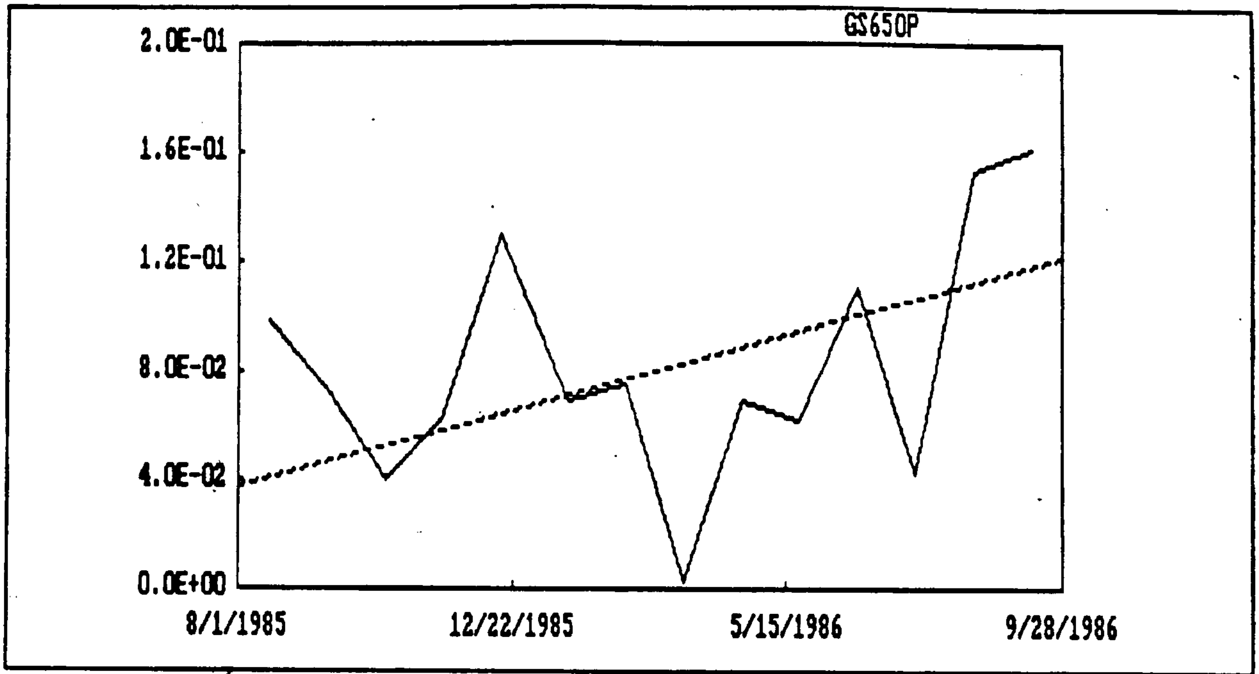

Figure D-13. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at USGS 07196500. Seasonal Kendall Sen Slope Estimate = 0.072 mg/l/yr.

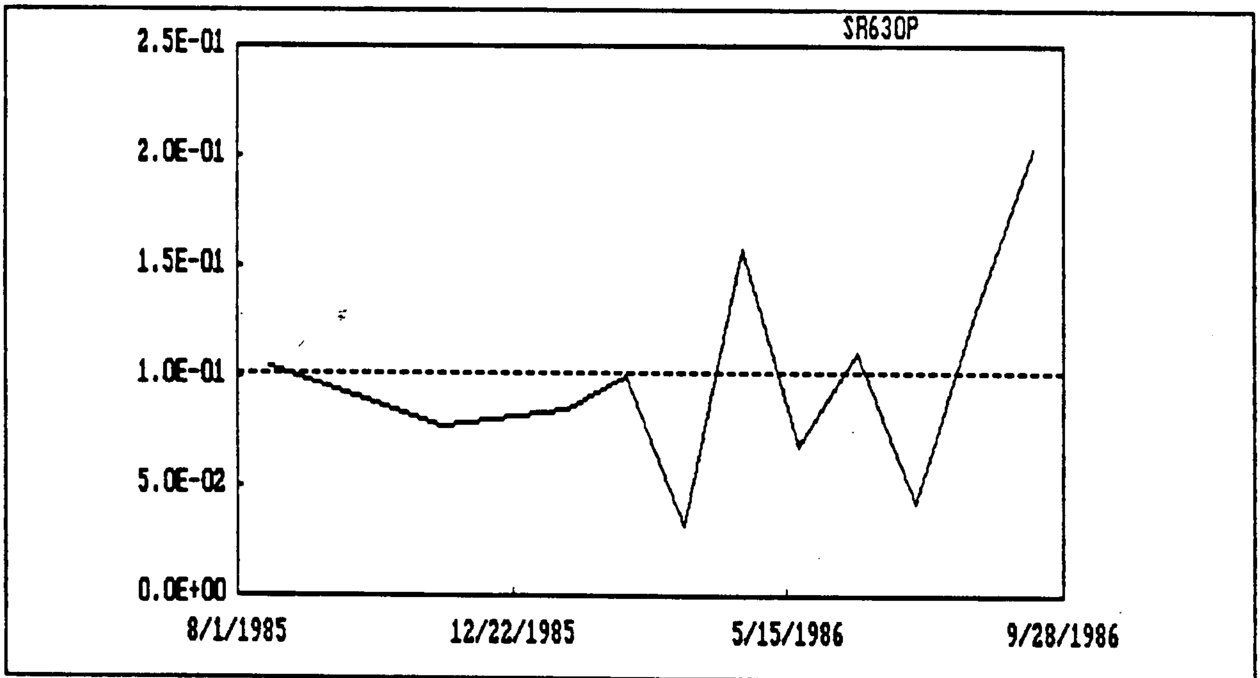

Figure D-14. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at SR 6.3. Seasonal Kendall Sen Slope Estimate = 0.00000 mg/l/yr.

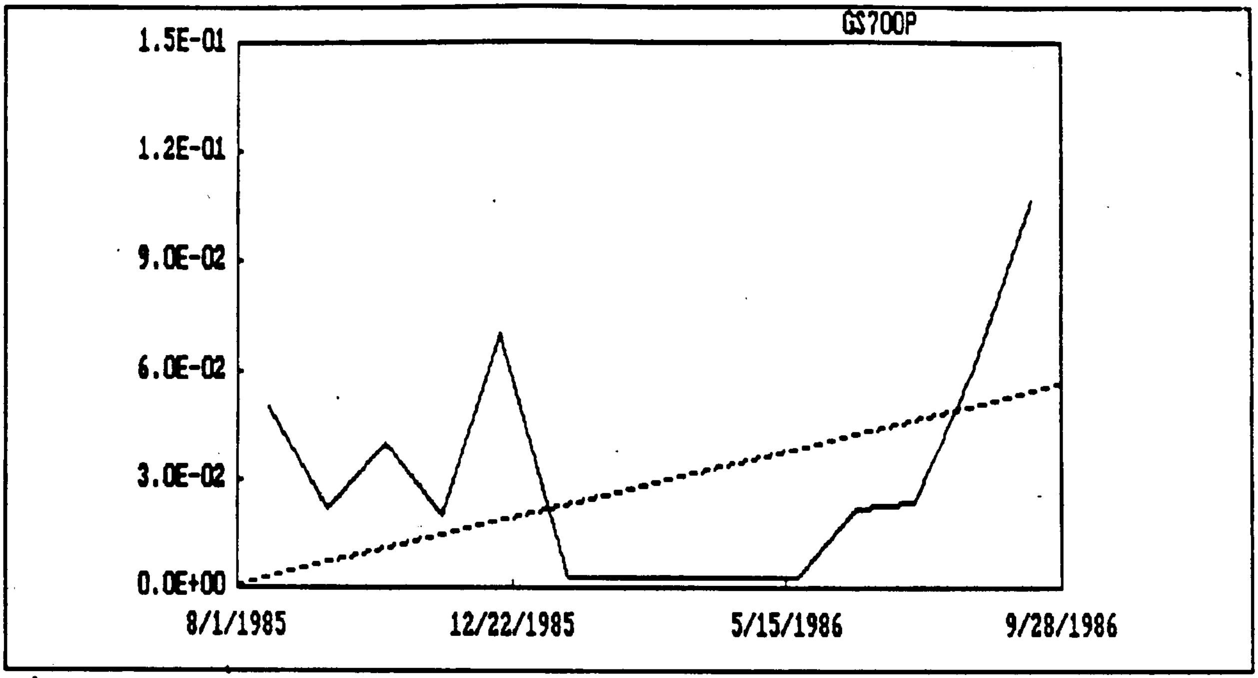

Figure D-15. Orthophosphate (as P) time series plot of monthly average concentration in mg/l at USGS 07197000. Seasonal Kendall Sen Slope Estimate = 0.047 mg/l/yr.

APPENDIX E

COMPARISON OF MEDIAN ORTHOPHOSPHATE CONCENTRATION OF UPSTREAM VS DOWNSTREAM STATIONS

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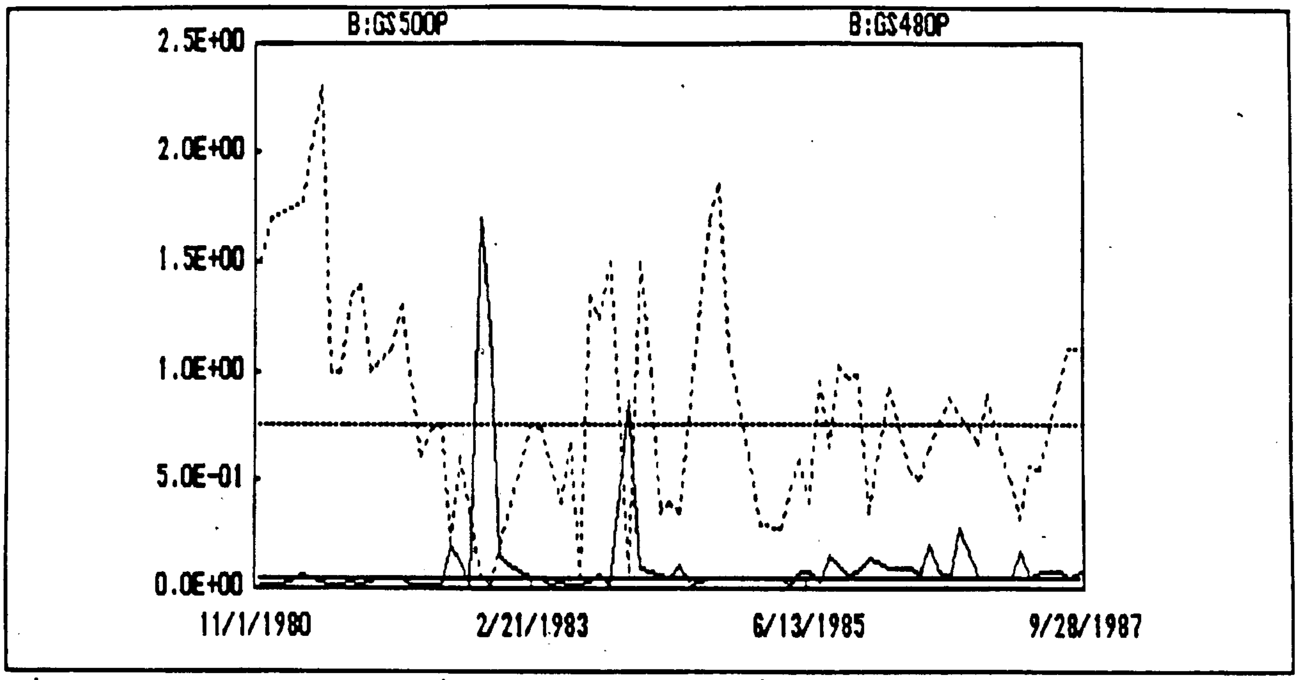

Figure E-1. Comparison of median orthophosphate (P) concentration at USGS 07194800 (solid) vs 07195000 (dashed line).

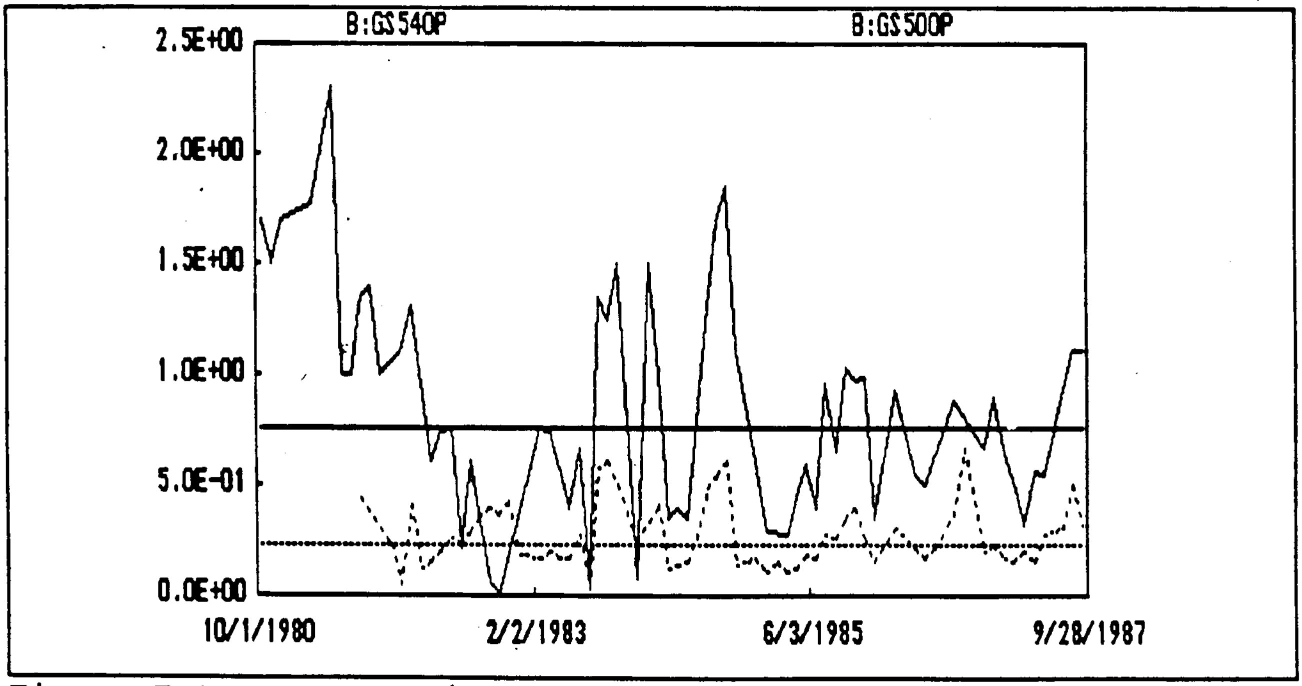

Figure E-2. Comparison of median orthophosphate(P) concentration (mg/l) at USGS 07195000 (solid) vs 07195400 (dashed line).

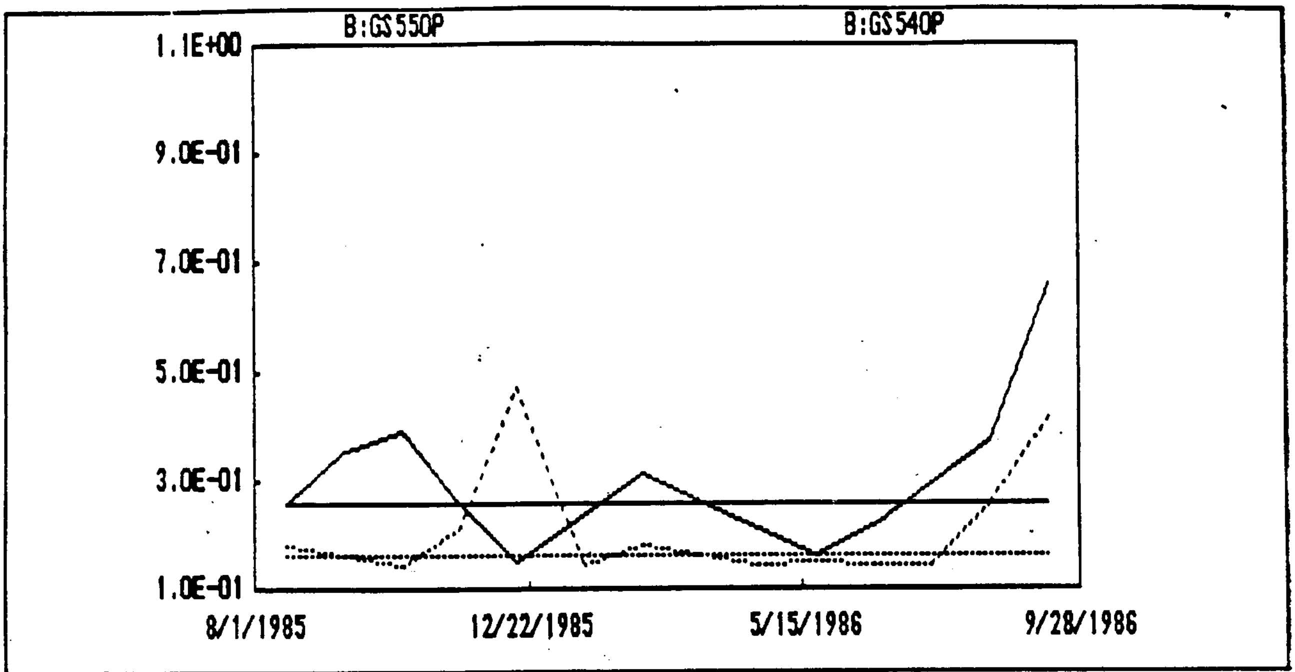

Figure E-3. Comparison of median orthophosphate(P) concentration (mg/l) of USGS 07195400 (solid) vs 07195500 (dashed line).

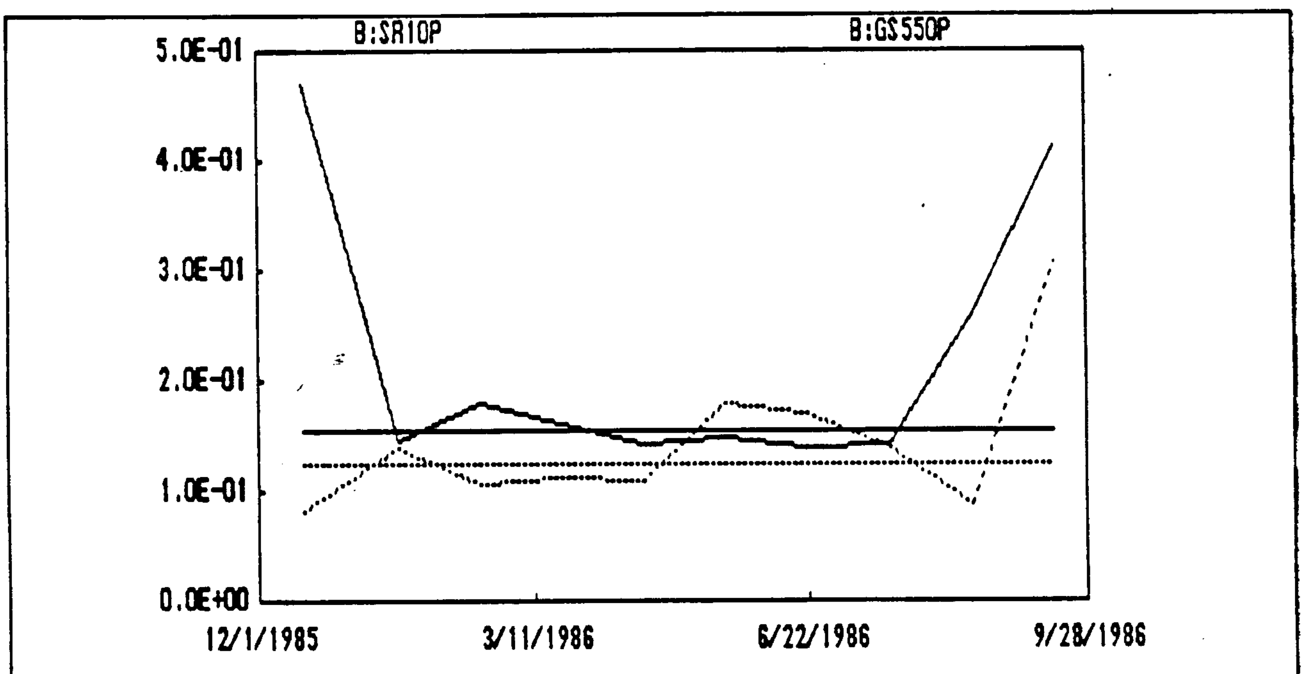

Figure E-4. Comparison of median orthophosphate(P) concentration (mg/l) of USGS 07195500 (solid) vs SR-1 (dashed line).

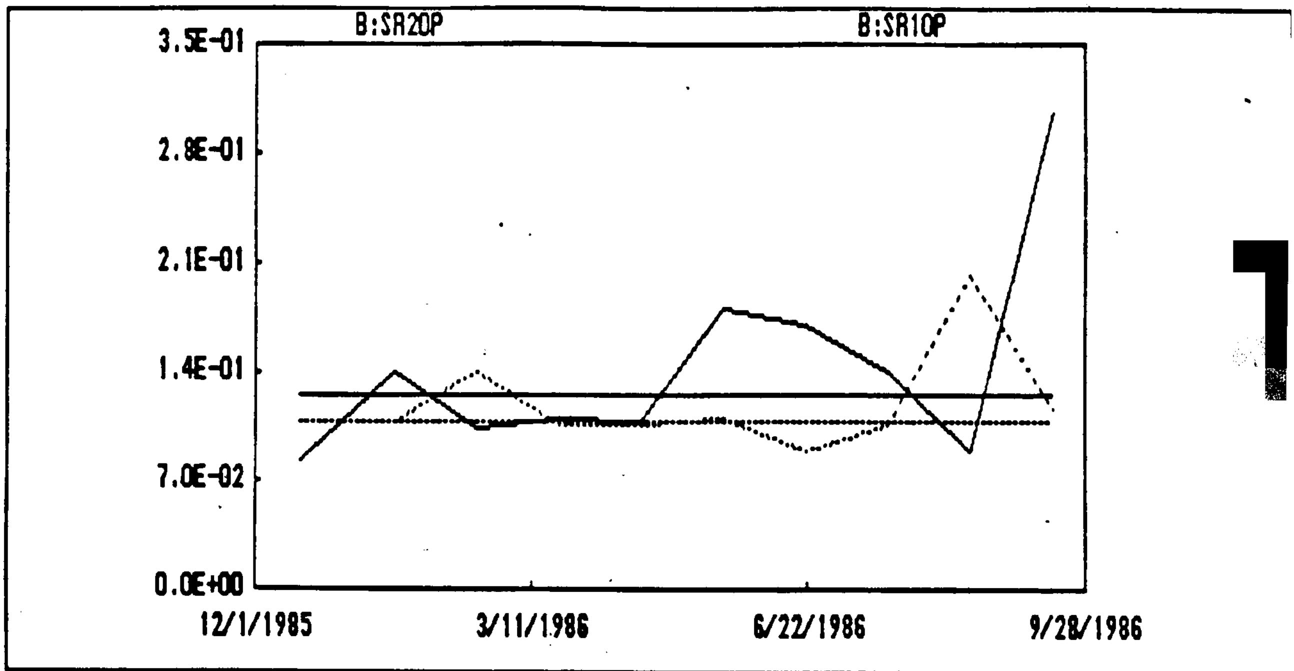

Figure E-5. Comparison of median orthophosphate(P) concentration (mg/l) at SR-1 (solid) vs SR-2 (dashed line).

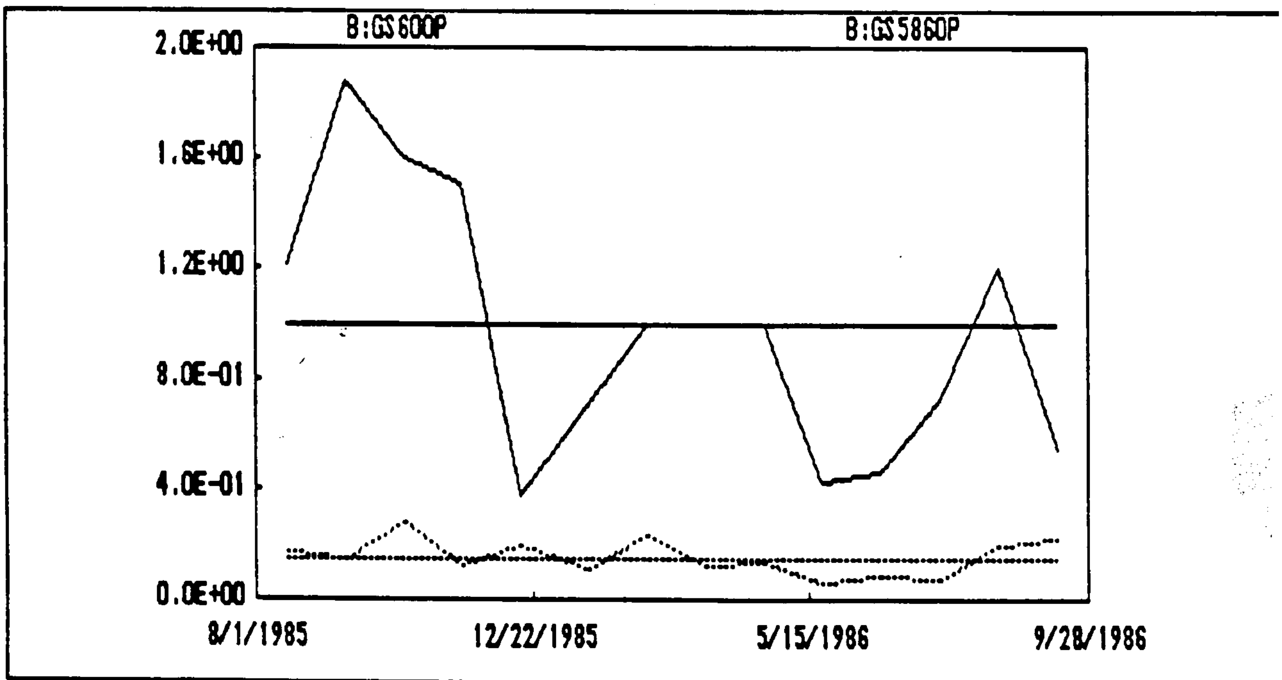

Figure E-6. Comparison of median orthophosphate(P) concentration (mg/l) at USGS 07195860 (solid) vs 07196000 (dashed line).

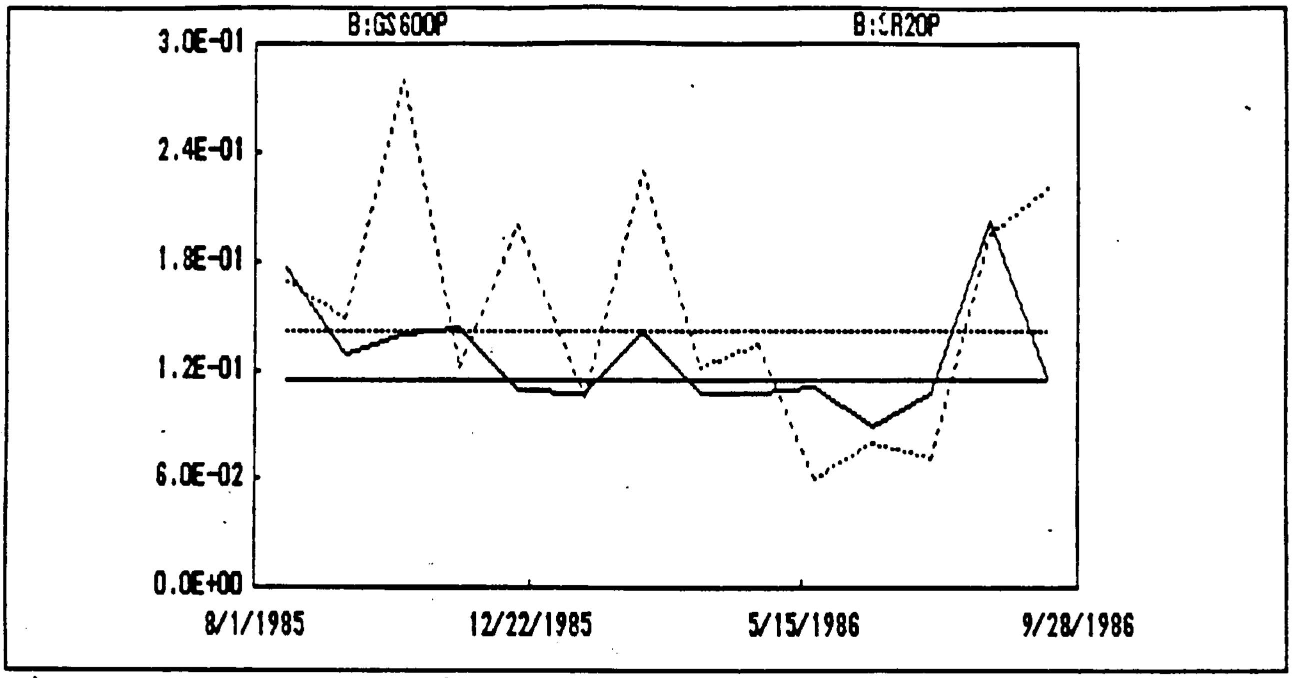

Figure E-7. Comparison of median orthophosphate(P) concentration (mg/l) at SR-2 (solid) vs USGS 07196000 (dashed line).

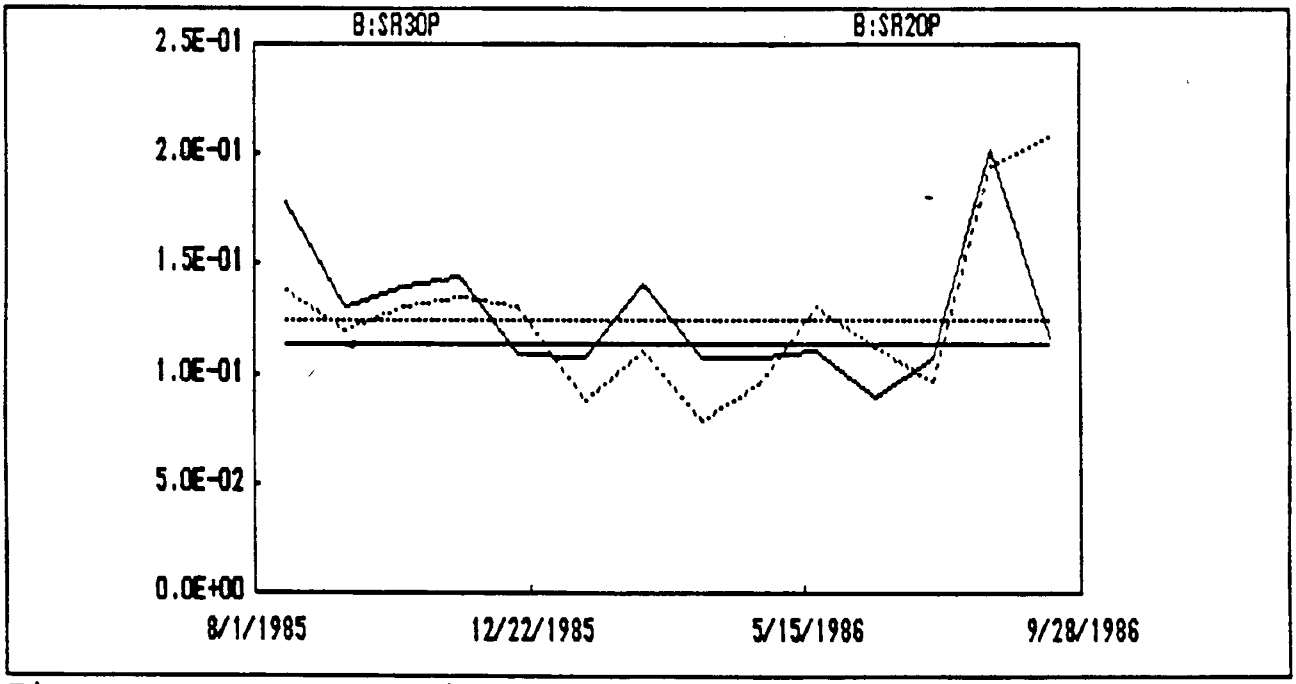

Figure E-8. Comparison of median orthophosphate(P) concentration (mg/l) at SR-2 (solid) vs SR-3 (dashed line).

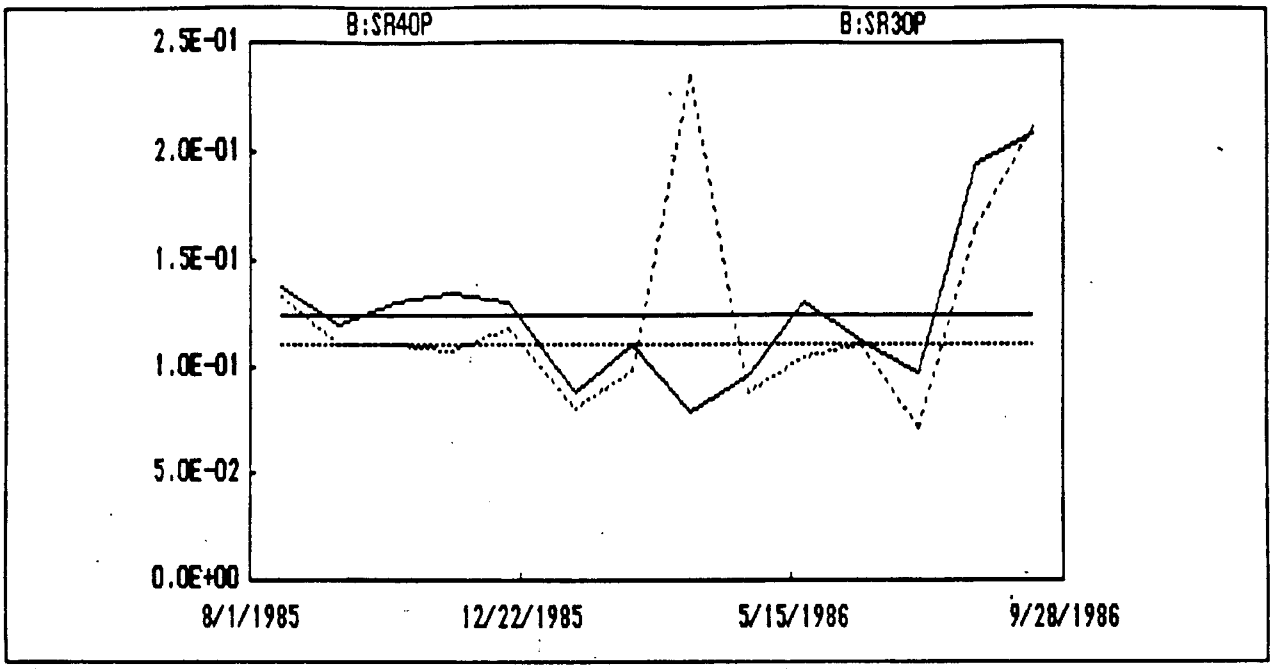

Figure E-9. Comparison of median orthophosphate(P) concentration (mg/l) at SR-3 (solid) vs SR-4 (dashed line).

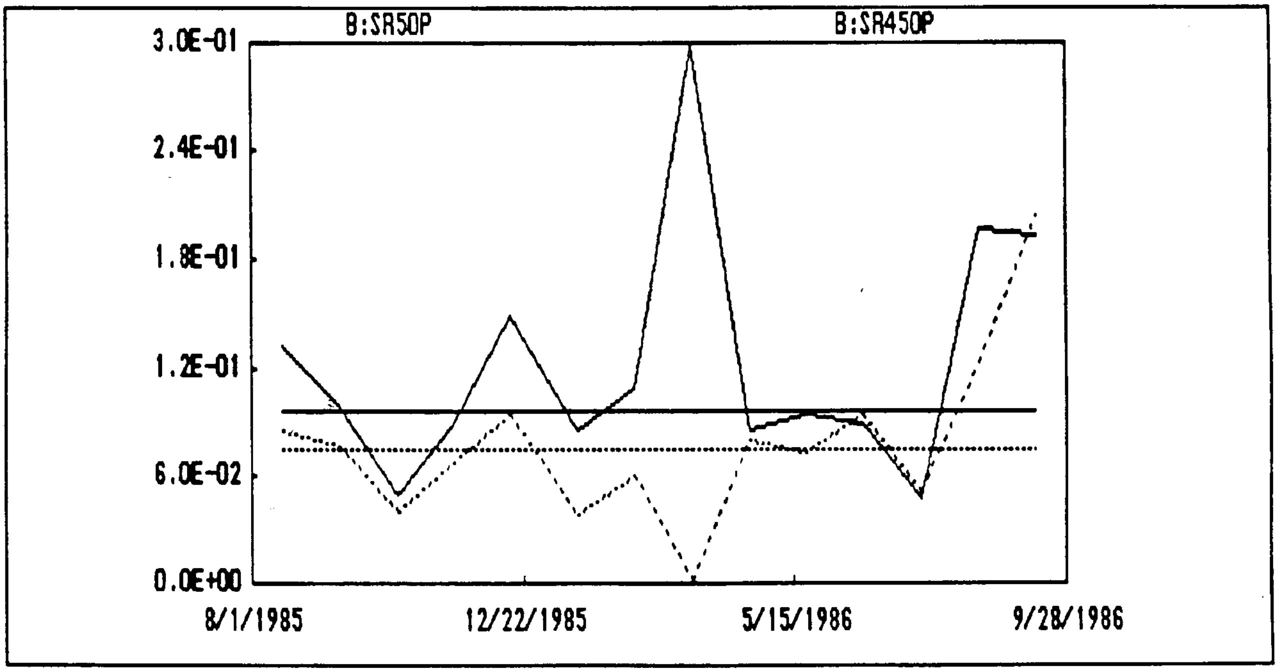

Figure E-10. Comparison of median orthophosphate(P) concentration (mg/l) at SR-4.5 (solid) vs SR-5 (dashed line).

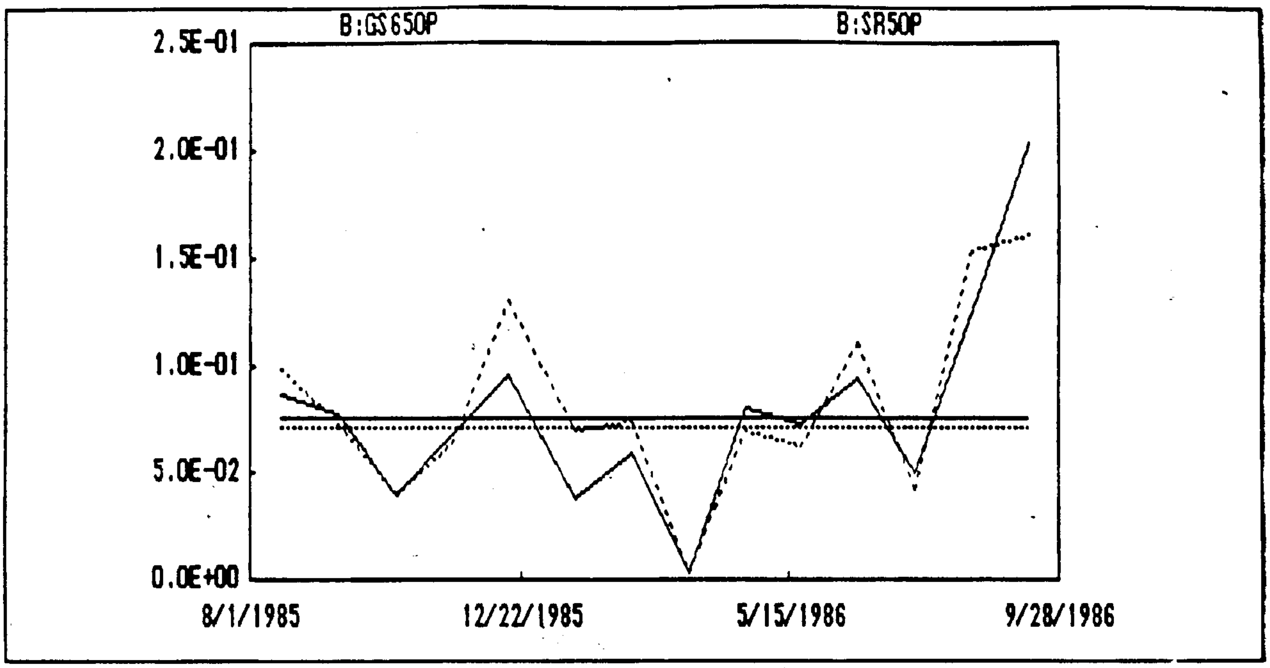

Figure E-11. Comparison of median orthophosphate(P) concentration (mg/l) at SR-5 (solid) vs USGS 07196500 (dashed line).

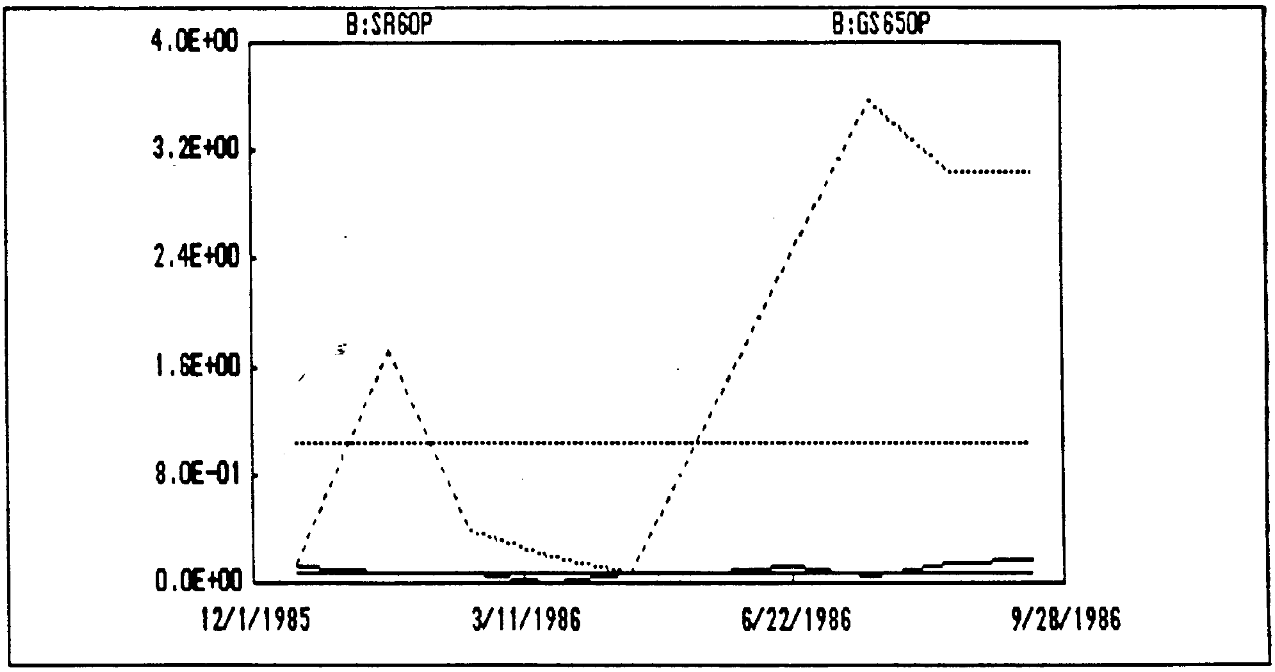

Figure E-12. Comparison of median orthophosphate(P) concentration (mg/l) at USGS 07196500 (solid) vs USGS 07196000 (dashed line).

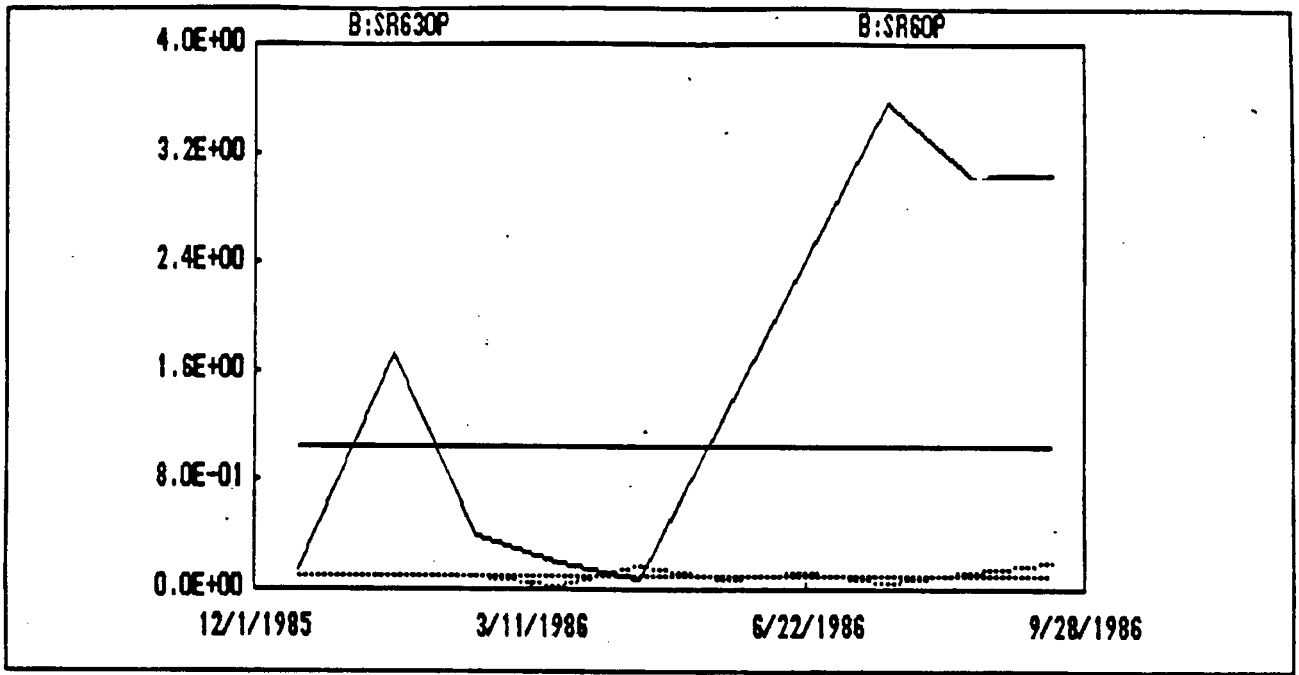

Figure E-13. Comparison of median orthophosphate(P) concentration (mg/l) at SR-6 (solid) vs SR-6.3 (dashed line).

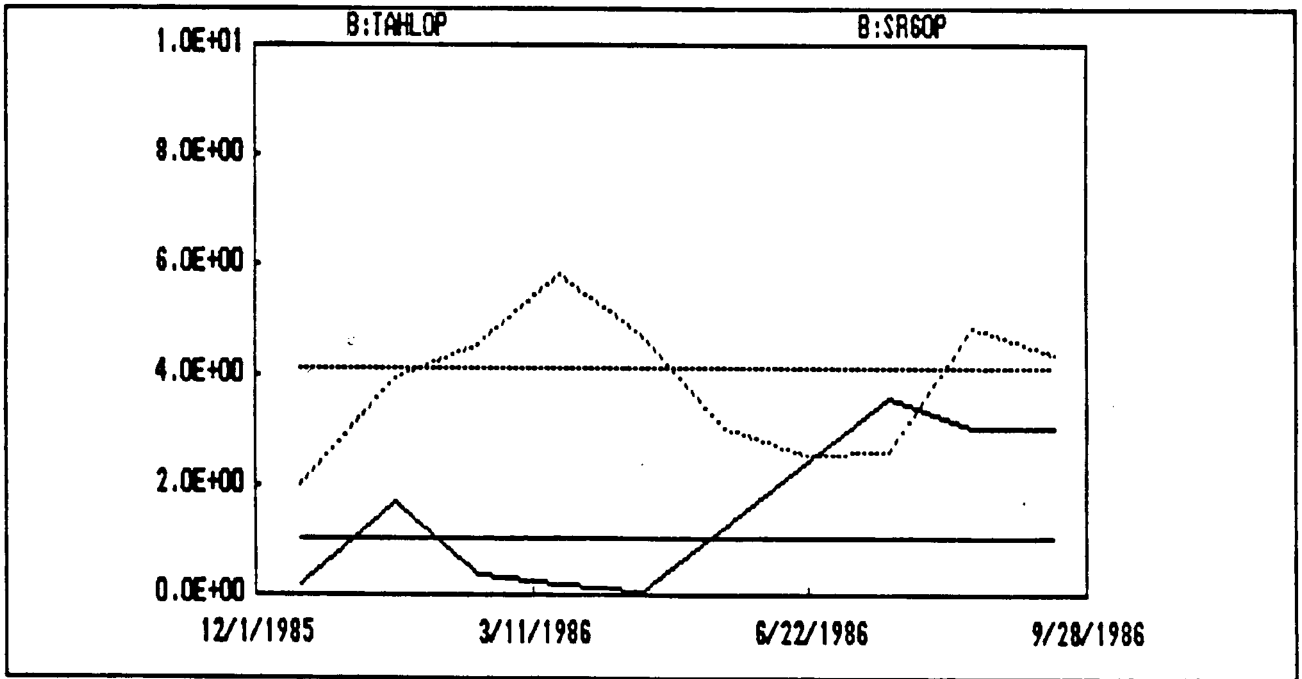

Figure E-14. Comparison of median orthophosphate(P) concentration (mg/l) at SR-6 (solid) vs Tahlequah STP (dashed line).

APPENDIX F

GRAPHIC ILLUSTRATION OF LONG TERM TEMPORAL TRENDS IN NITRITE + NITRATE (N) CONCENTRATION IN ILLINOIS RIVER

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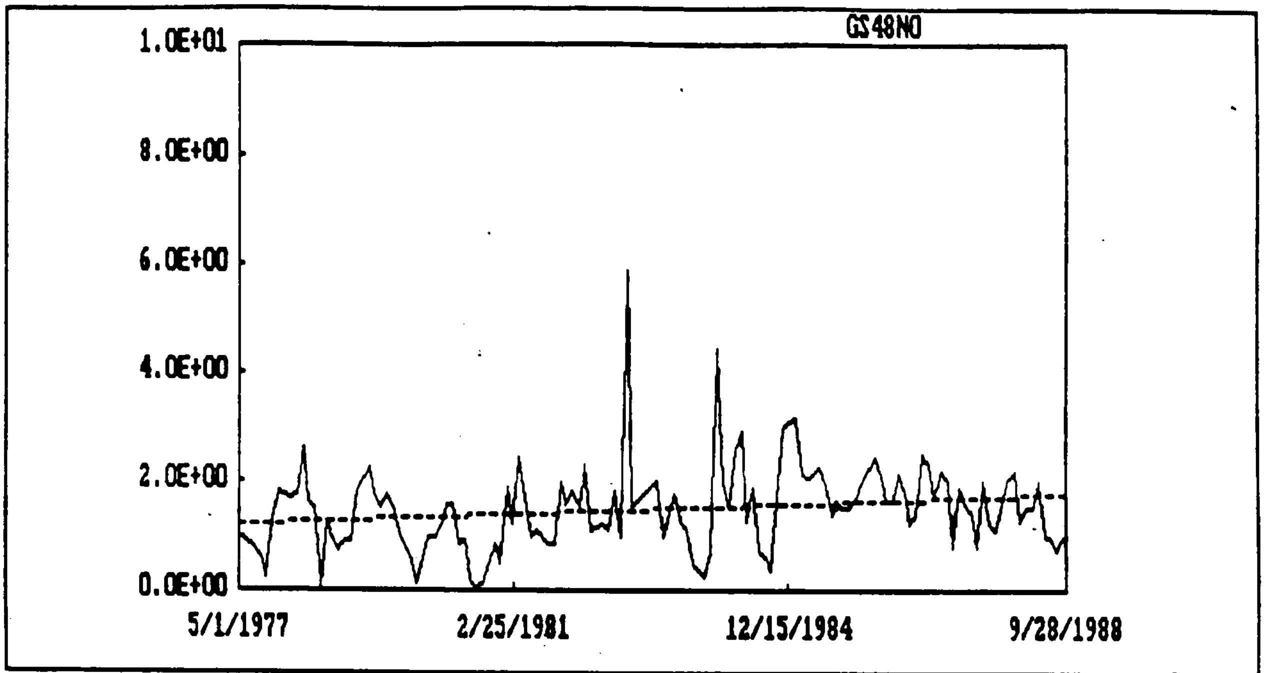

Figure F-1. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at USGS 07194800. Seasonal Kendall Sen Slope Estimate = 0.050 mg/l/yr.

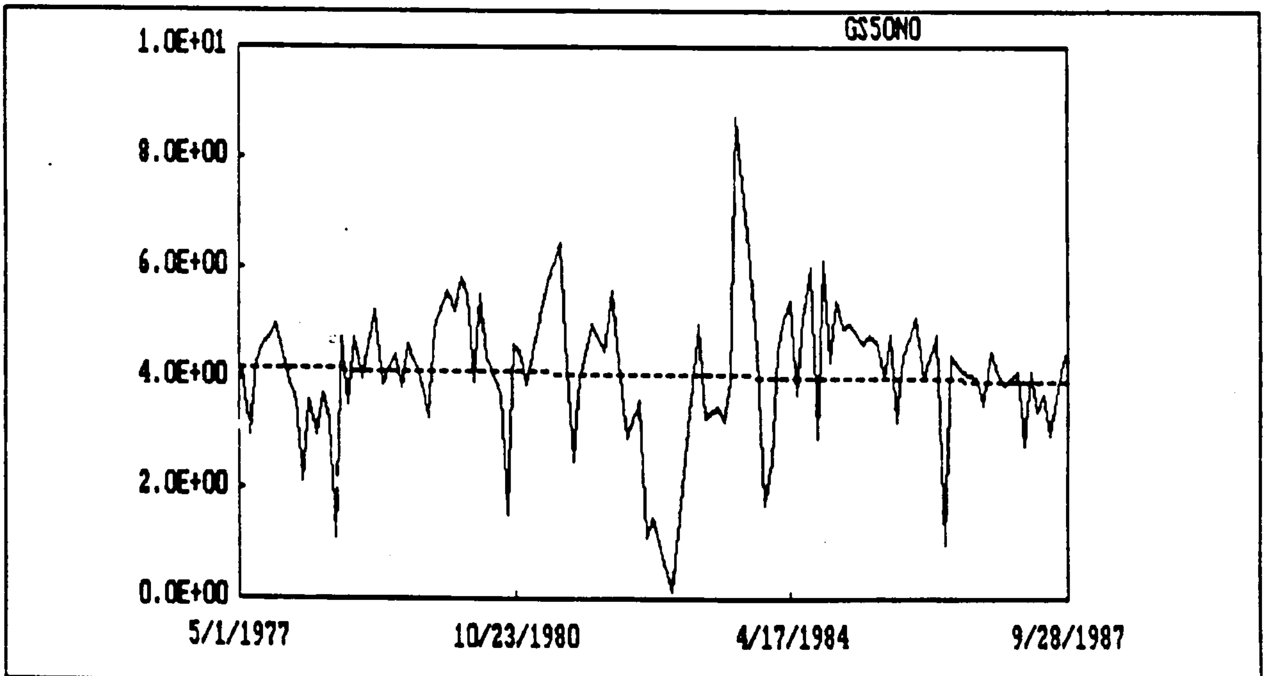

Figure F-2. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at USGS 07195000. Seasonal Kendall Sen Slope Estimate = -0.025 mg/l/yr.

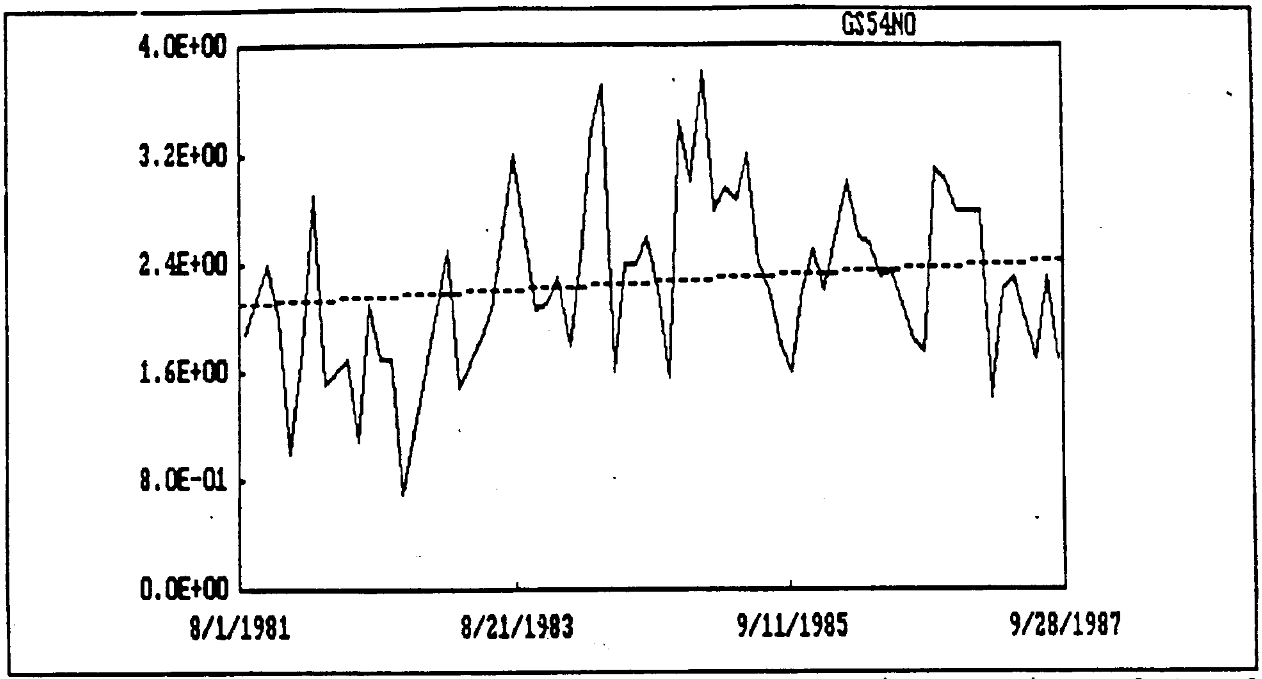

Figure F-3. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at USGS 07195400. Seasonal Kendall Sen Slope Estimate = 0.050 mg/l/yr.

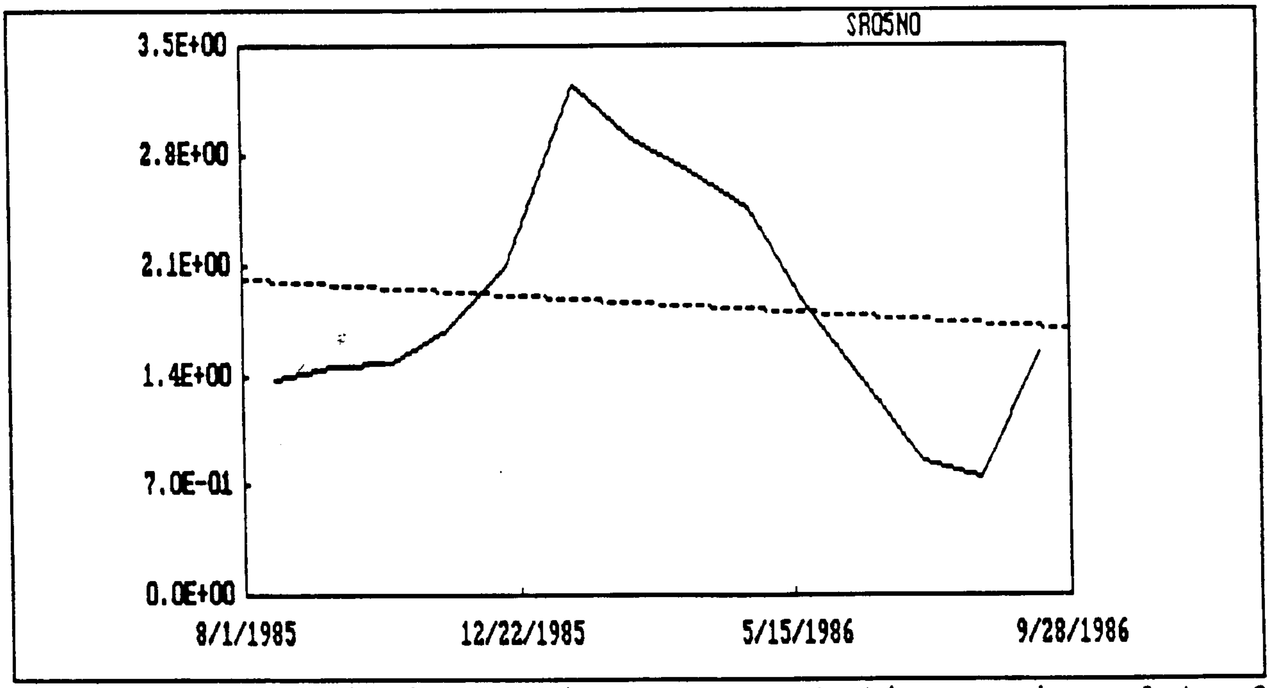

Figure F-4. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at SR 0.5. Seasonal Kendall Sen Slope Estimate = -0.272 mg/l/yr.

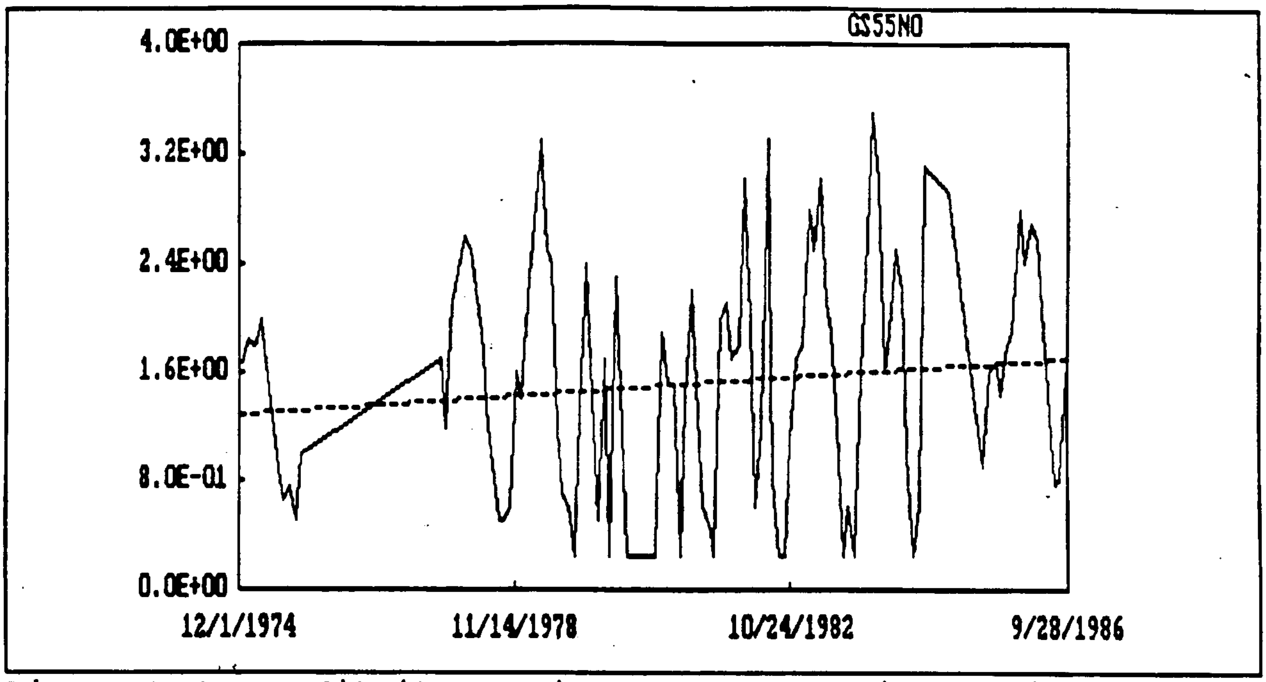

Figure F-5. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at USGS 07195500. Seasonal Kendall Sen Slope Estimate = 0.033 mg/l/yr.

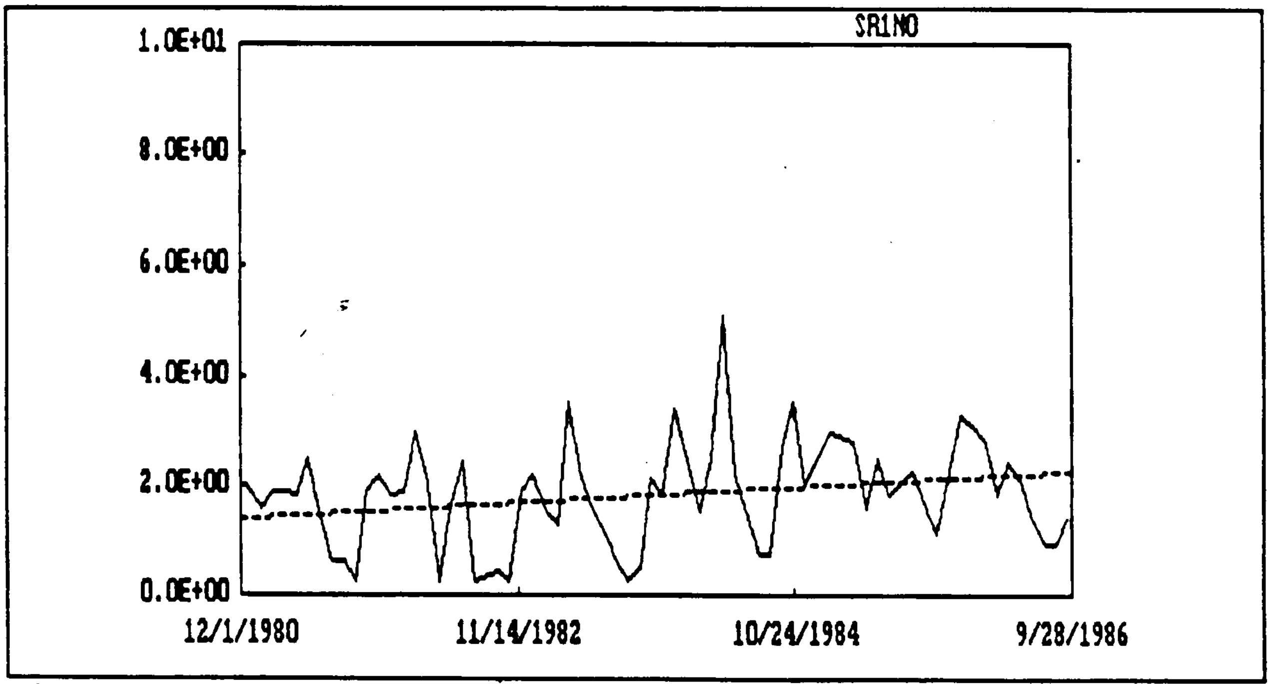

Figure F-6. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at SR 1. Seasonal Kendall Sen Slope Estimate = 0.150 mg/l/yr.

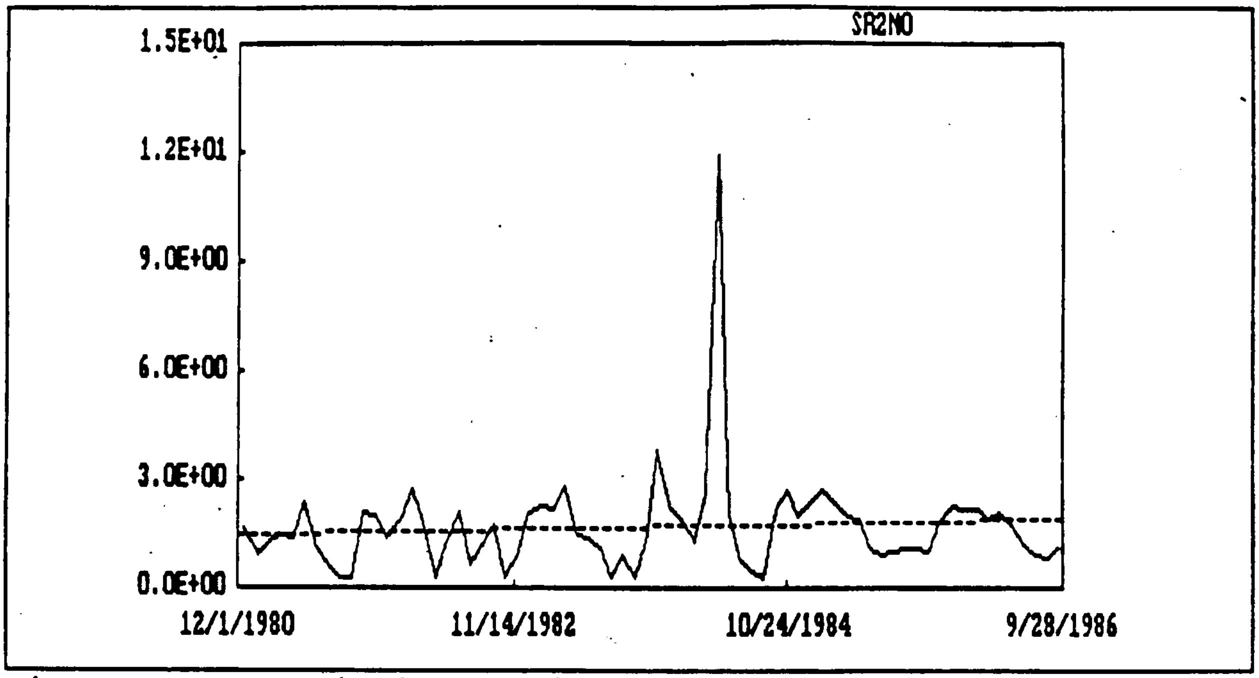

Figure F-7. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at SR 2. Seasonal Kendall Sen Slope Estimate = 0.075 mg/l/yr.

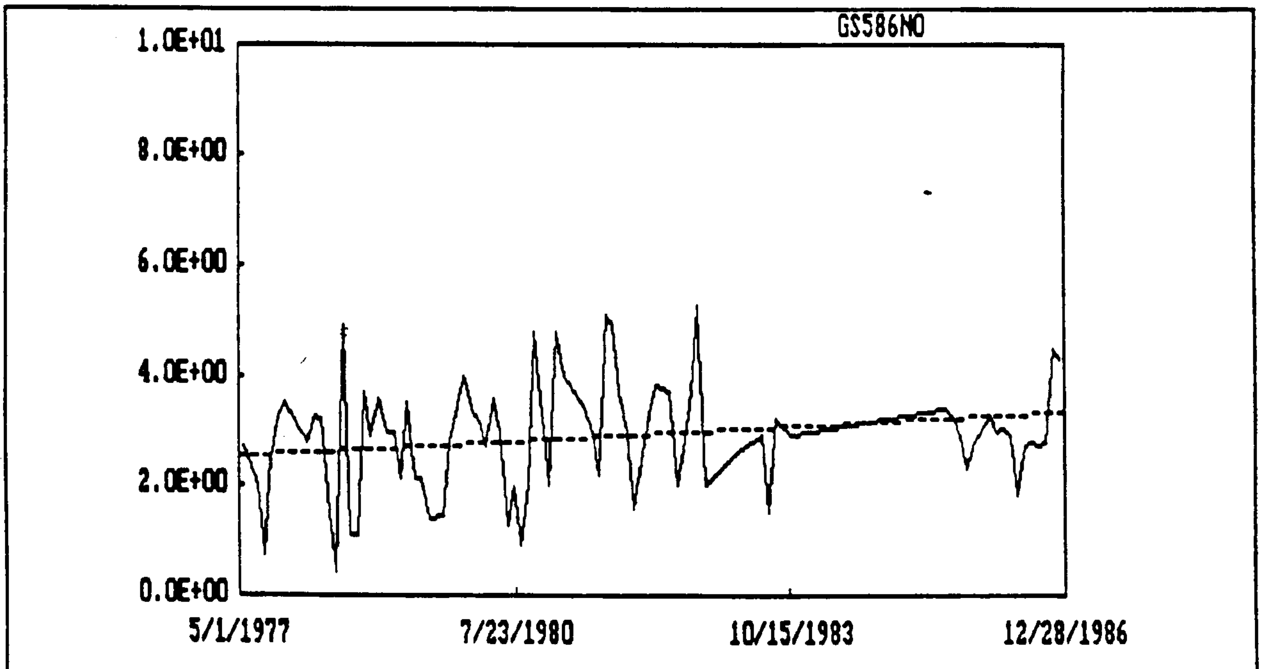

Figure F-8. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at USGS 07195860. Seasonal Kendall Sen Slope Estimate = 0.085 mg/l/yr.

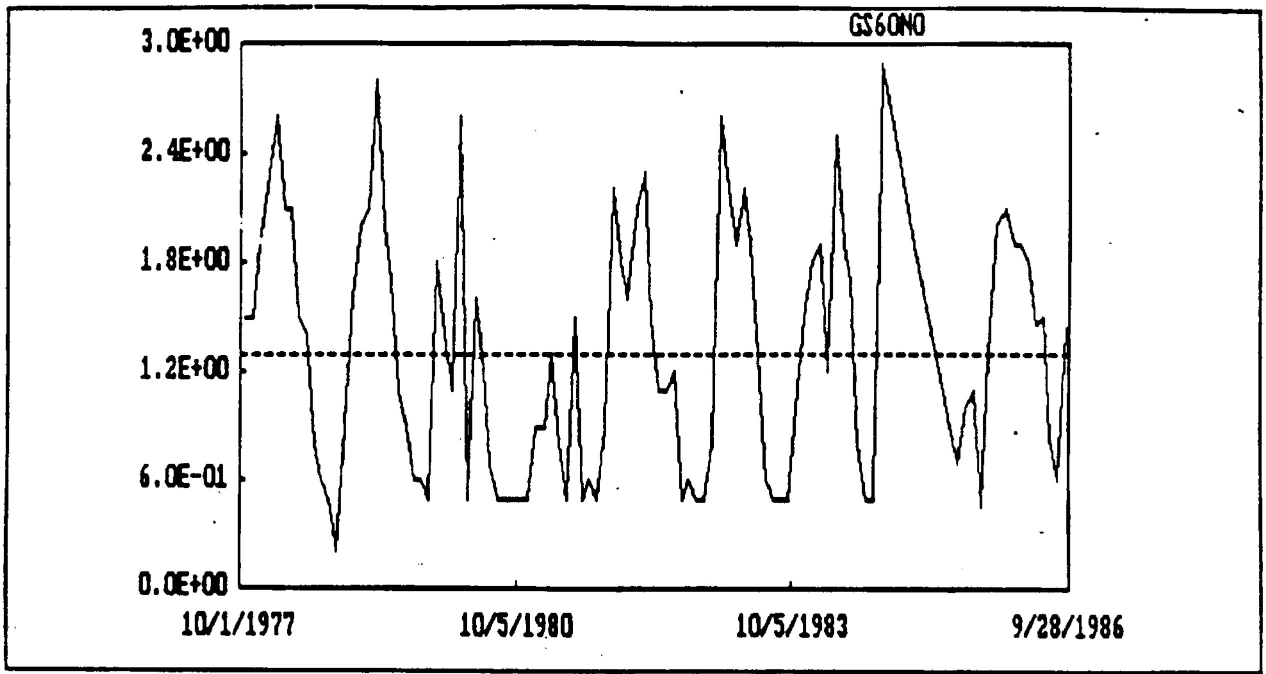

Figure F-9. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at USGS 07196000. Seasonal Kendall Sen Slope Estimate = 0.000 mg/l/yr.

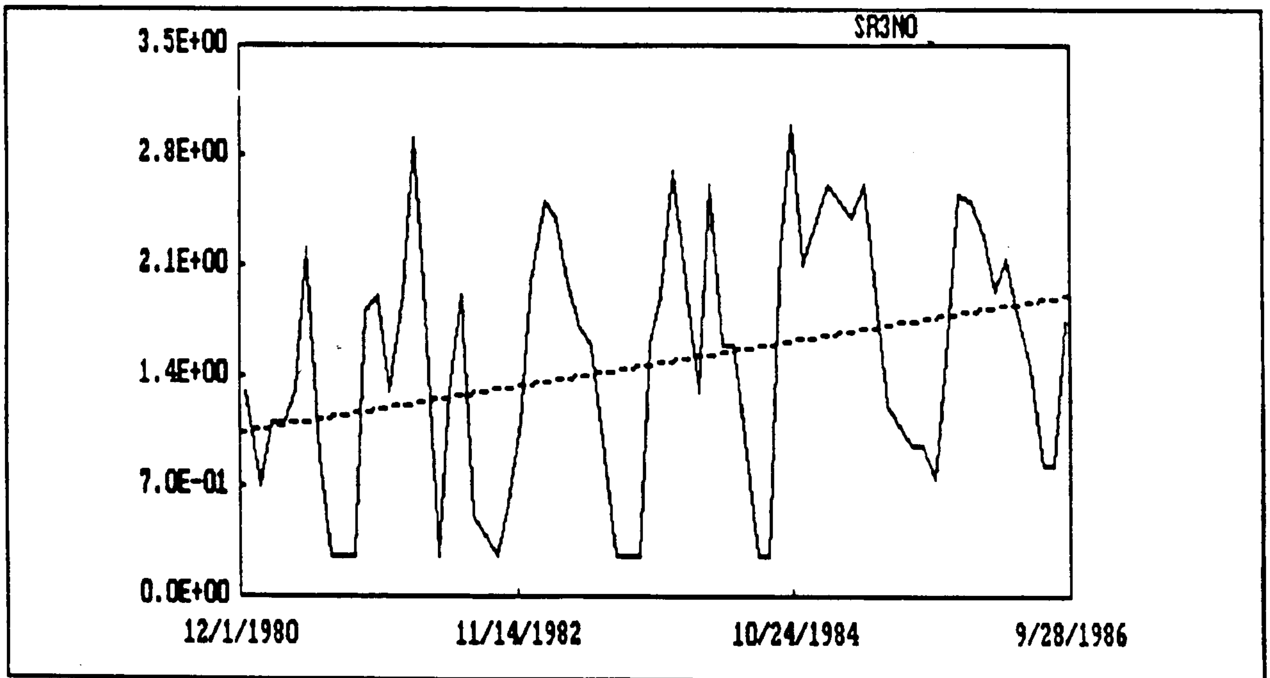

Figure F-10. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at SR 3. Seasonal Kendall Sen Slope Estimate = 0.150 mg/l/yr.

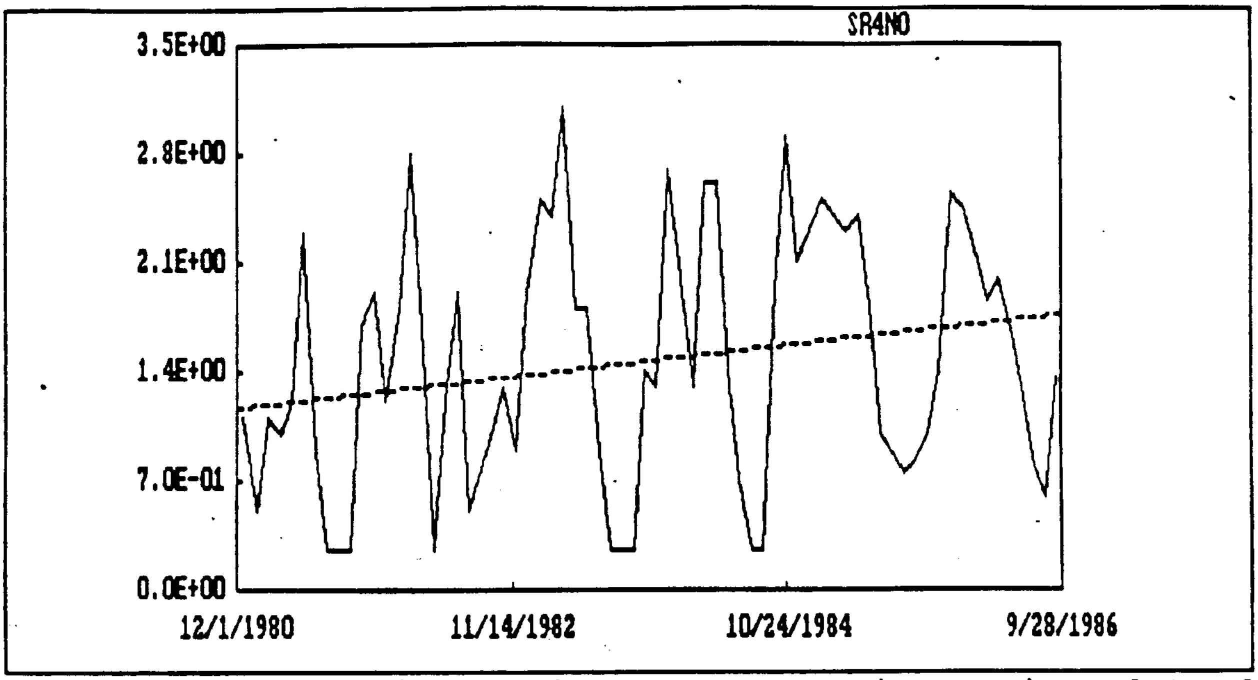

Figure F-11. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at SR 4. Seasonal Kendall Sen Slope Estimate = 0.102 mg/l/yr.

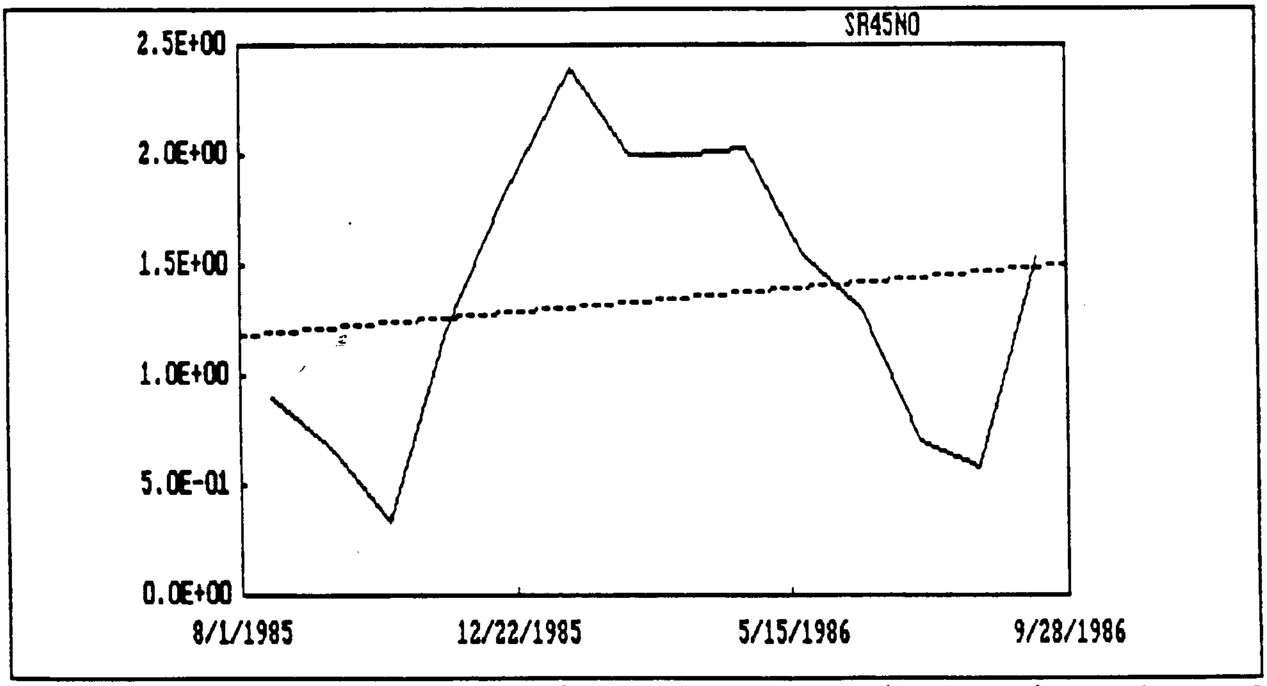

Figure F-12. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at SR 4.5. Seasonal Kendall Sen Slope Estimate = 0.269 mg/l/yr.

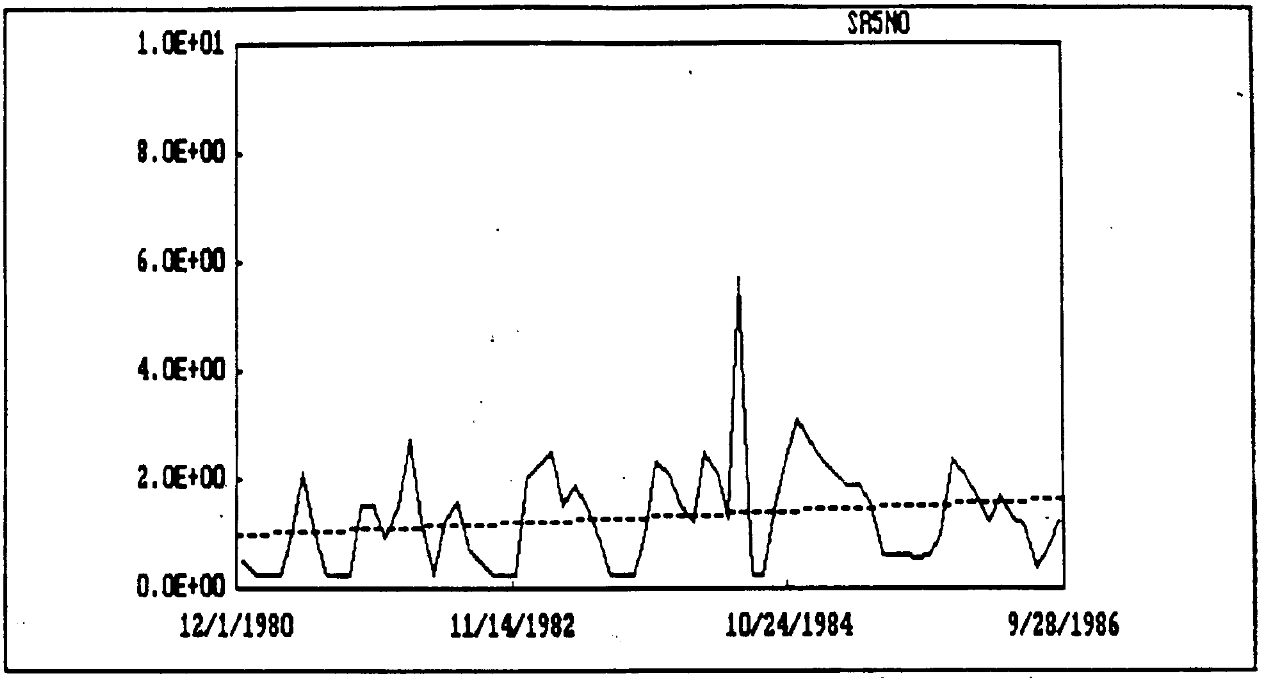

Figure F-13. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at SR 5. Seasonal Kendall Sen Slope Estimate = 0.109 mg/l/yr.

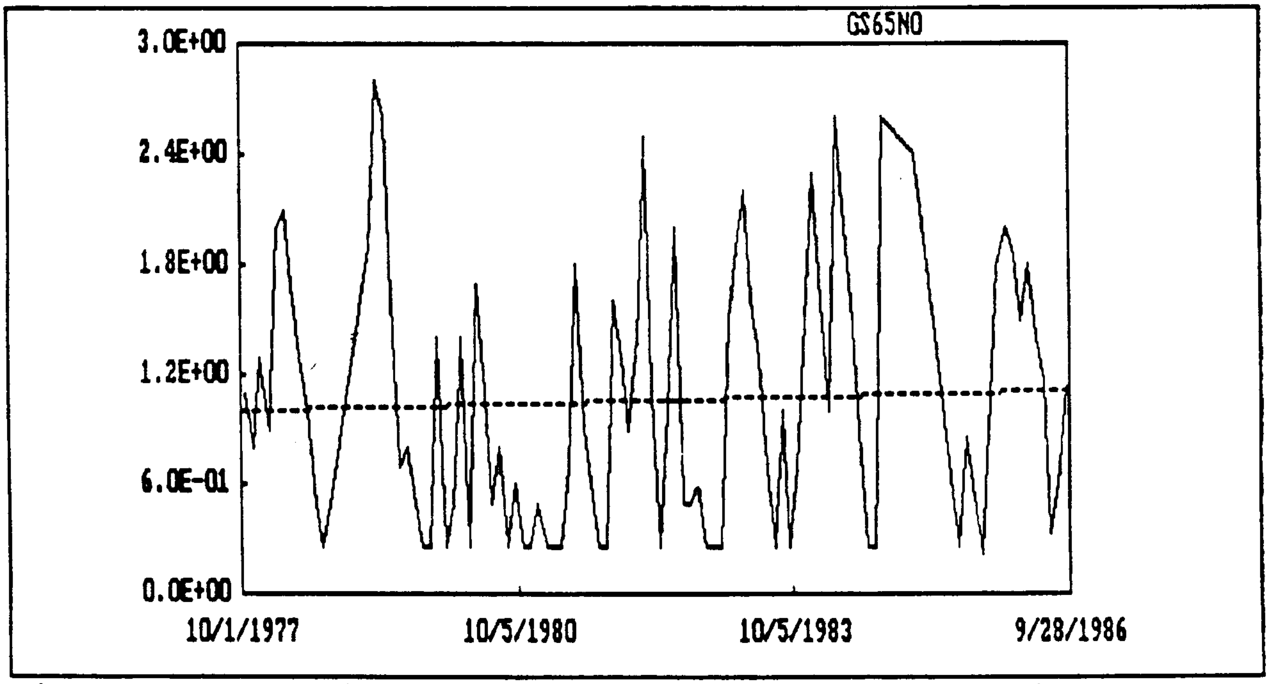

Figure F-14. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at USGS 07196500. Seasonal Kendall Sen Slope Estimate = 0.012 mg/l/yr.

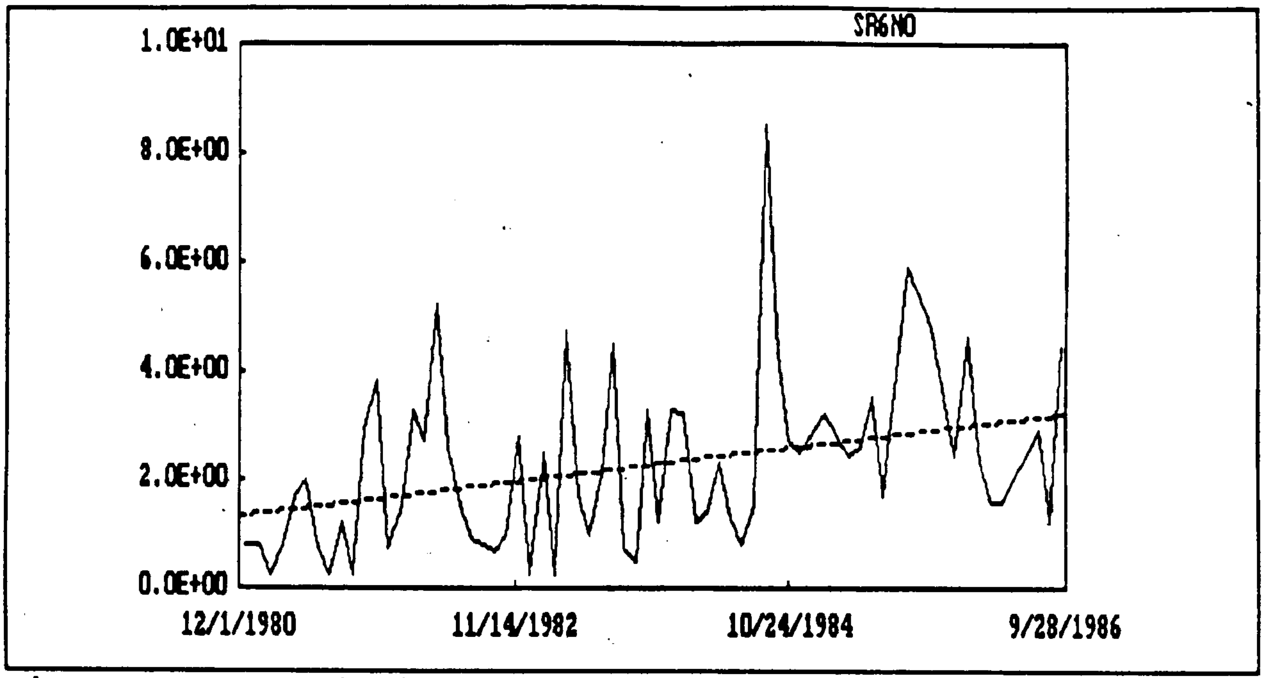

Figure F-15. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at SR 6. Seasonal Kendall Sen Slope Estimate = 0.320 mg/l/yr.

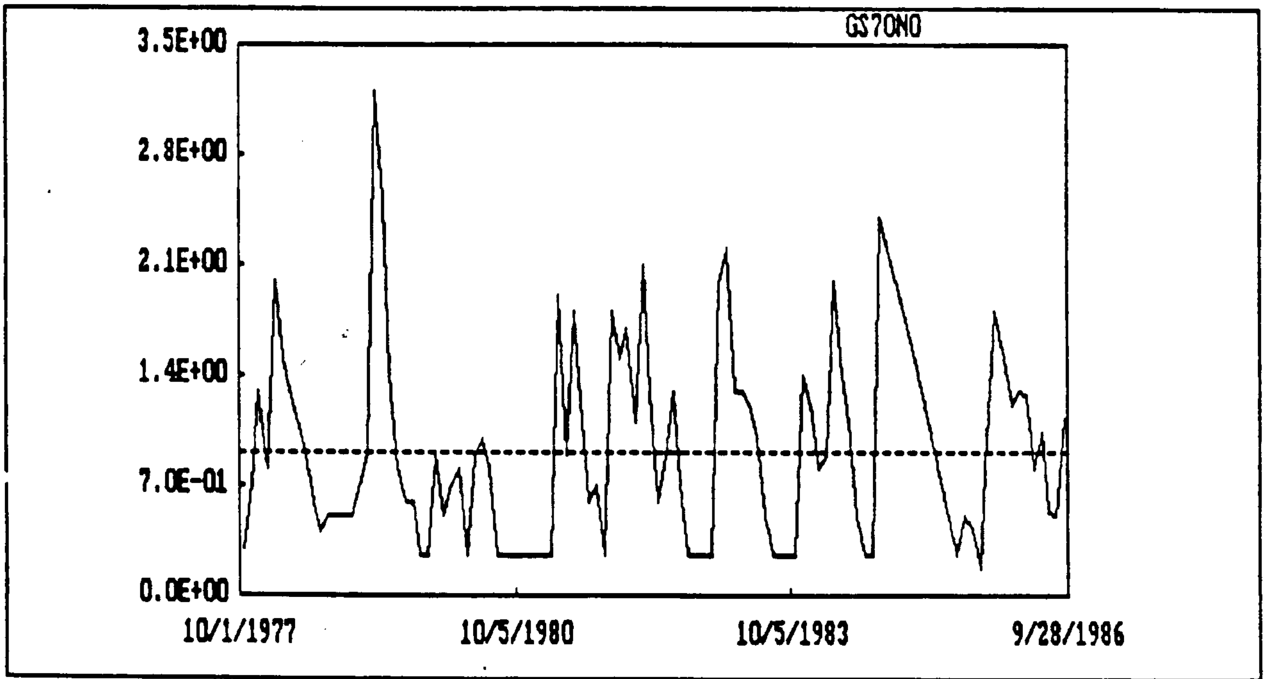

Figure F-16. Nitrite + nitrate (as N) time series plot of monthly average concentration in mg/l at USGS 07197000. Seasonal Kendall Sen Slope Estimate = 0.000 mg/l/yr.

APPENDIX G

COMPARISON OF MEDIAN NO2+NO3(N)

CONCENTRATION OF

UPSTREAM VS DOWNSTREAM STATIONS

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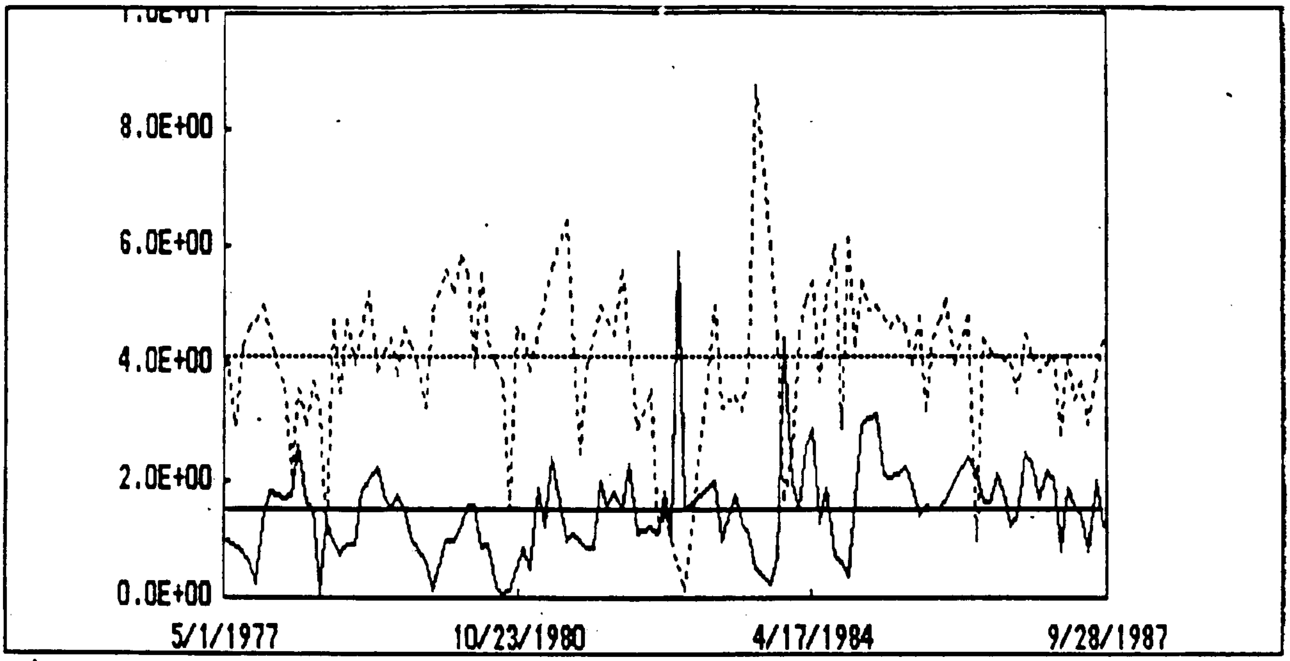
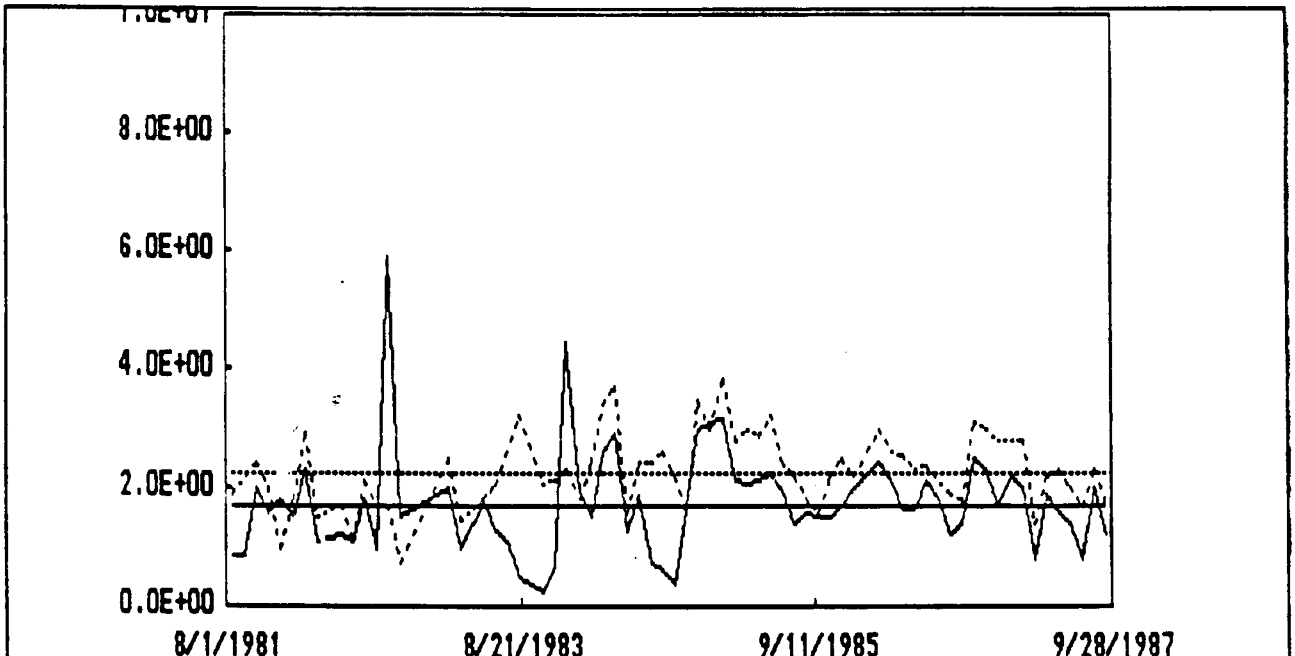


Figure G-1. Comparison of median NO2+NO3(N) concentration of USGS 07194800 (solid line) vs USGS 07195000 (dashed line) using the Wilcoxon signed rank test.



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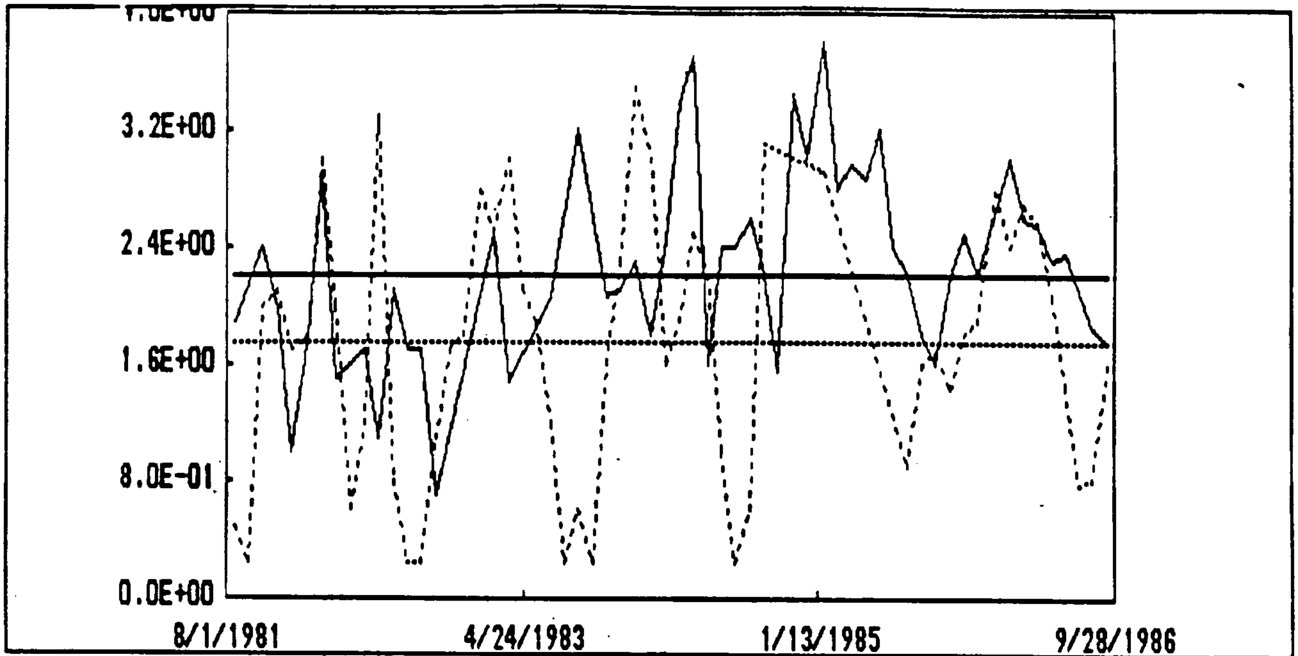

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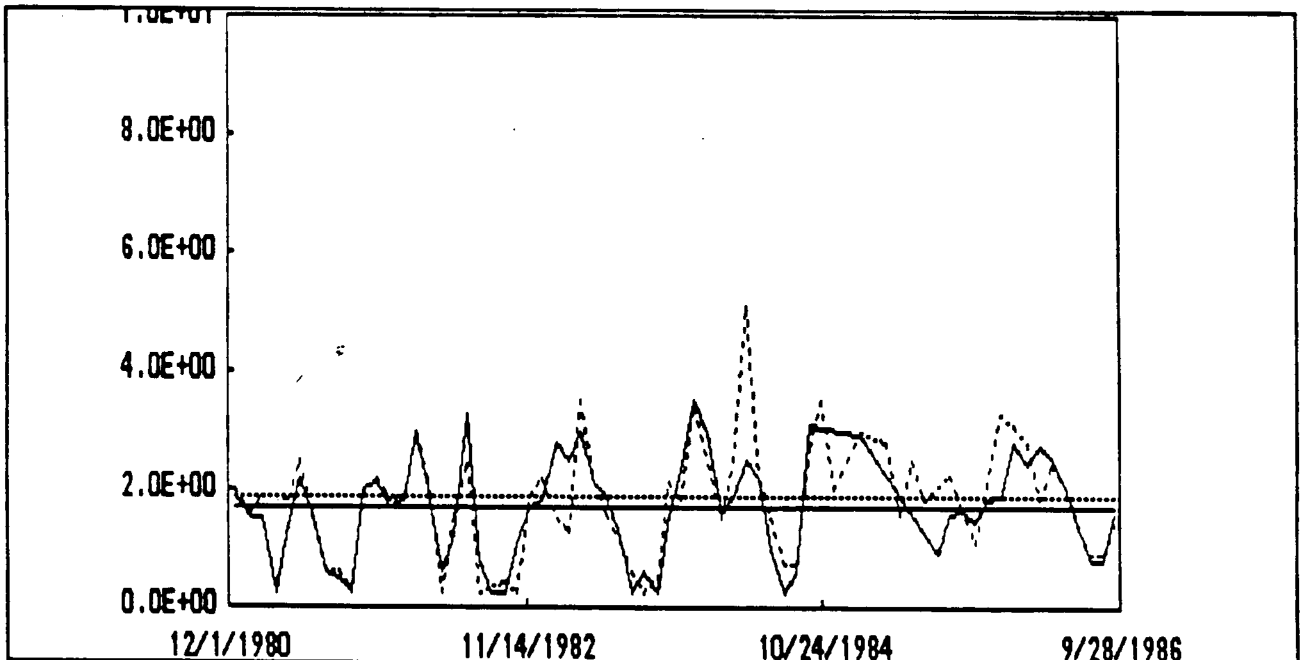

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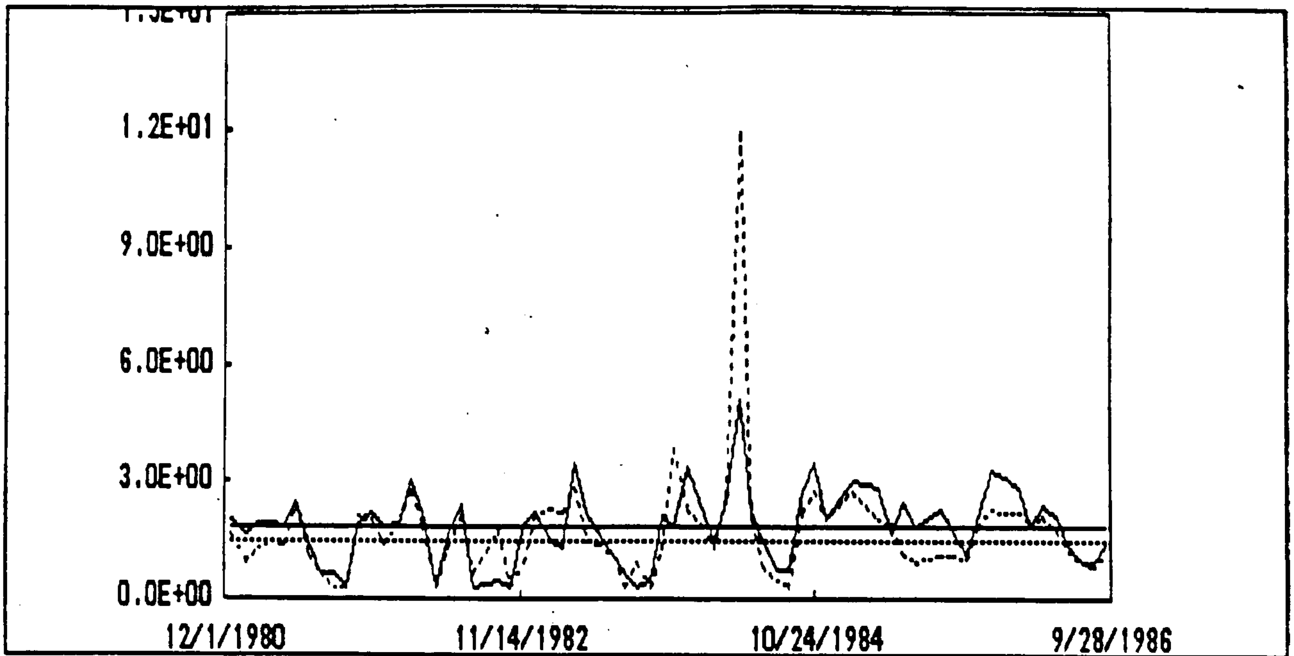

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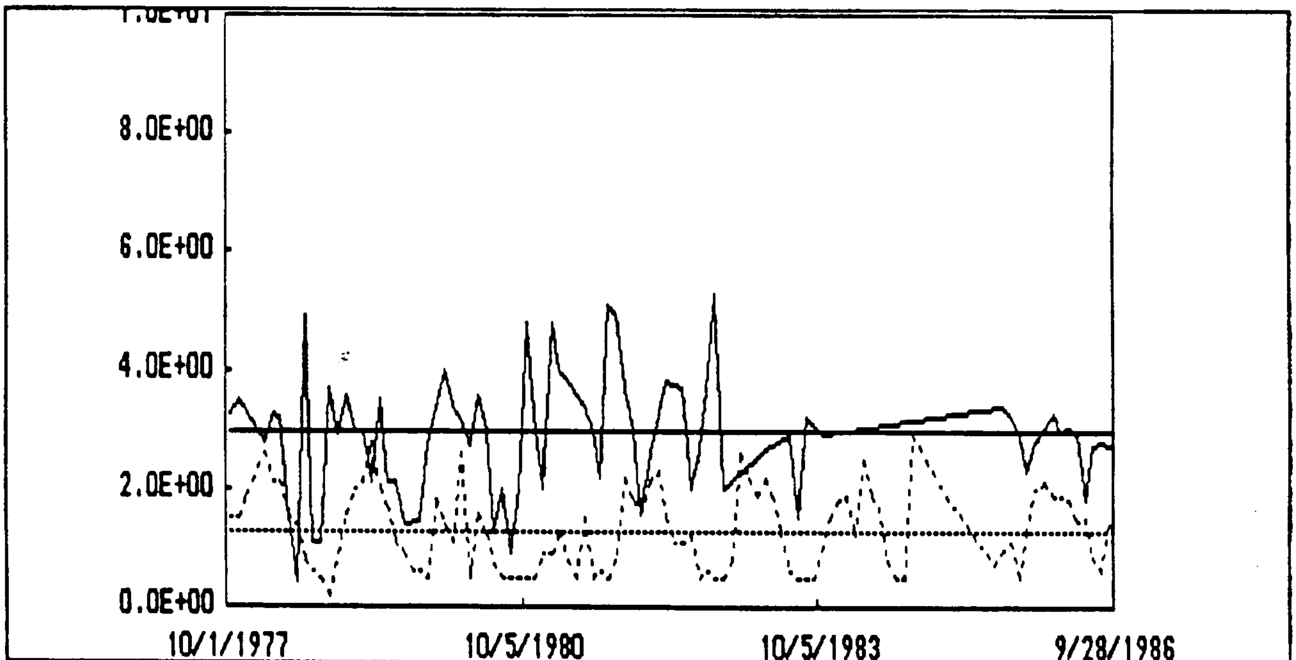

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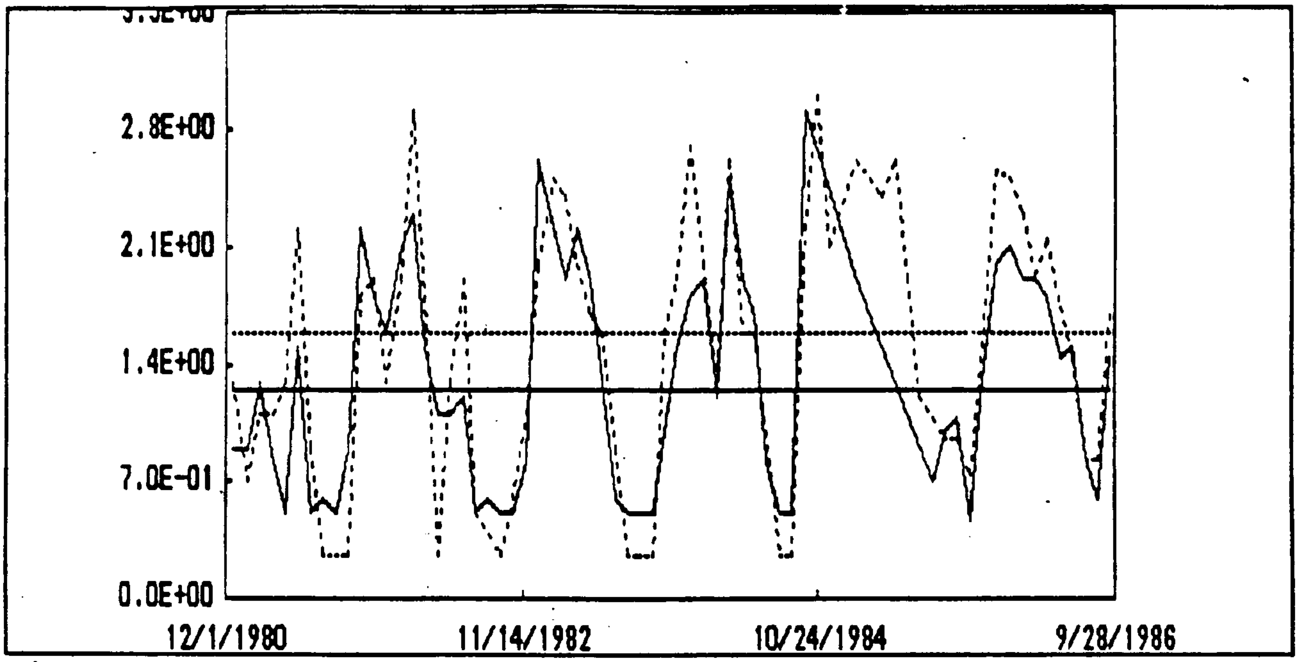

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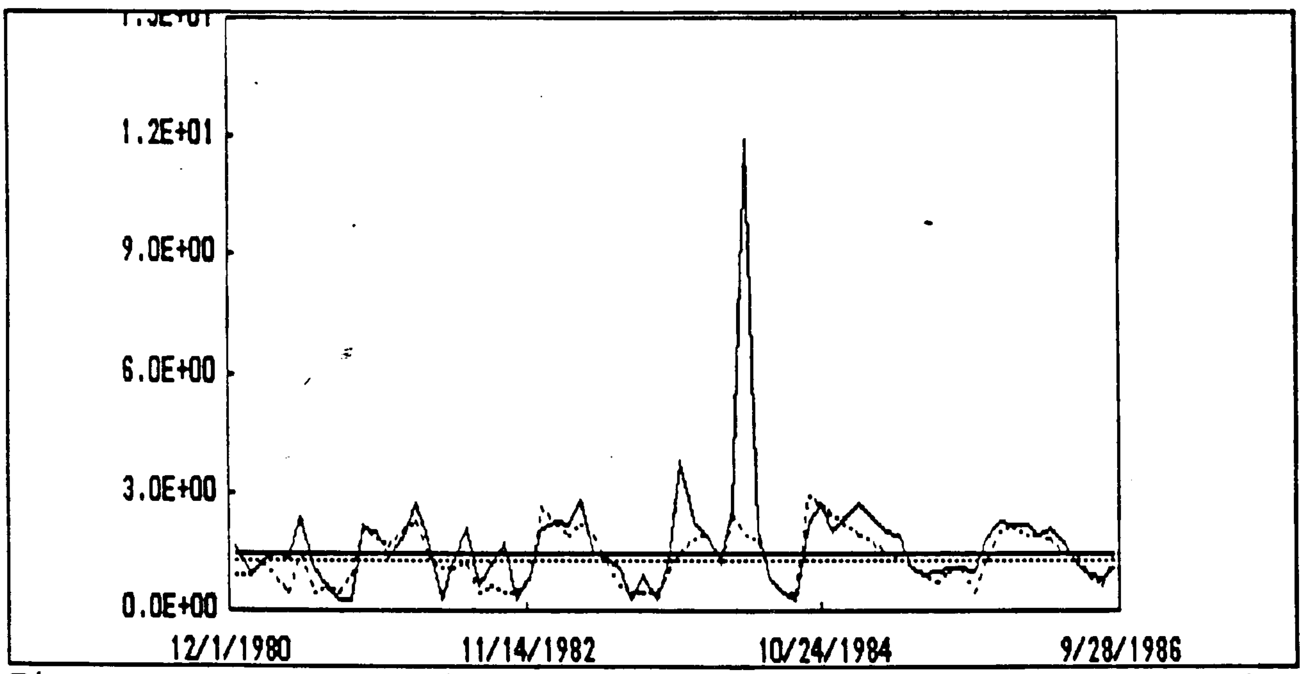

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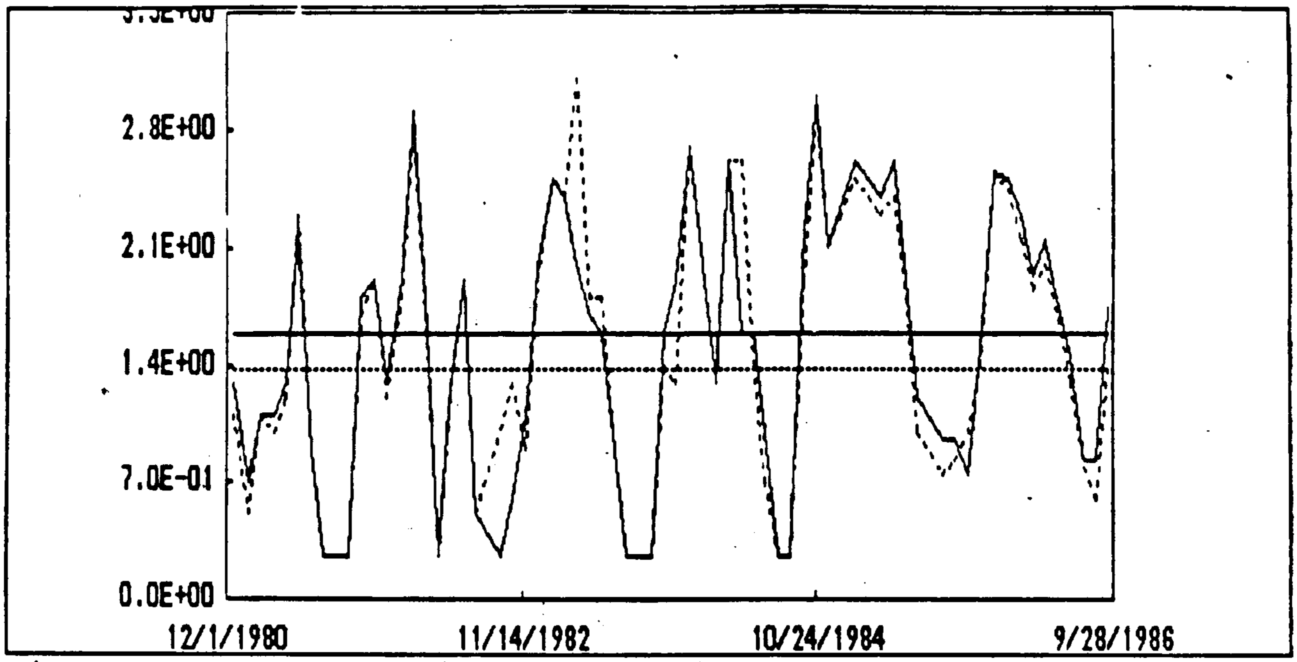

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GRAPHIC ILLUSTRATION OF LONG TERM TEMPORAL TRENDS AND COMPARISON OF MEDIAN AMMONIA(N) CONCENTRATION OF UPSTREAM VS DOWNSTREAM STATIONS

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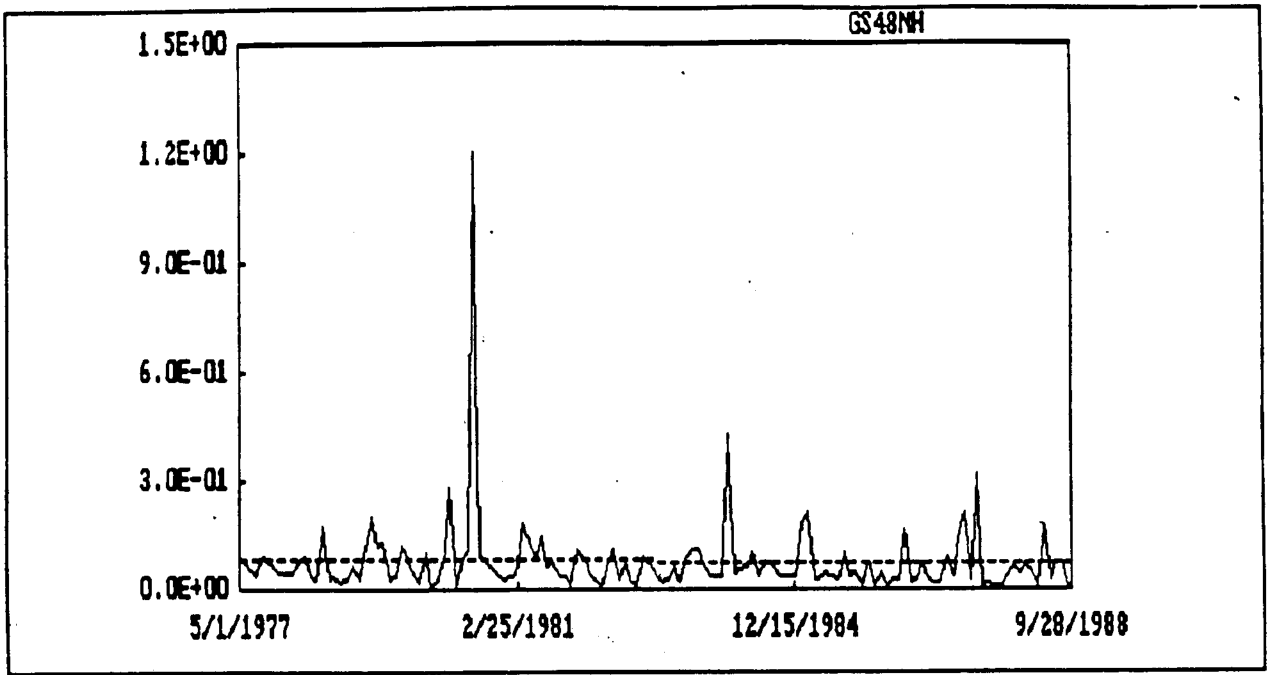
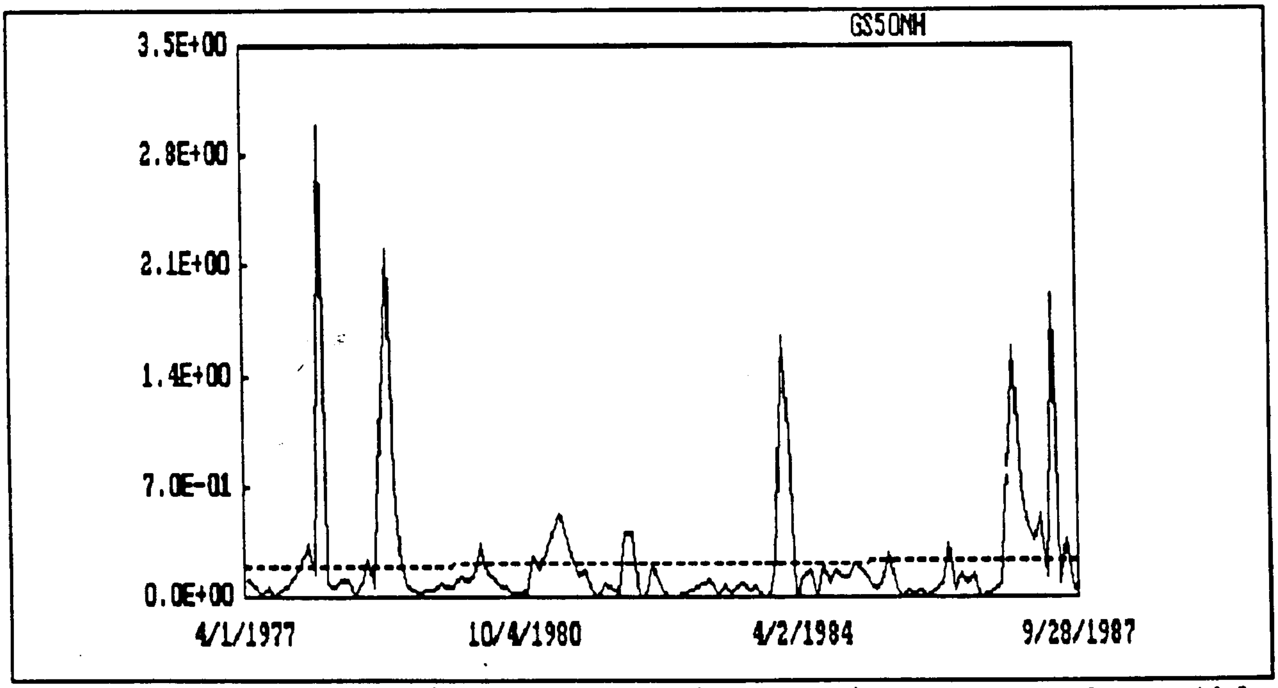


Figure H-1. Ammonia (as N) time series plot of monthly average concentration in mg/l at USGS 07194800. Seasonal Kendall Sen Slope Estimate = -0.001 mg/l/yr.



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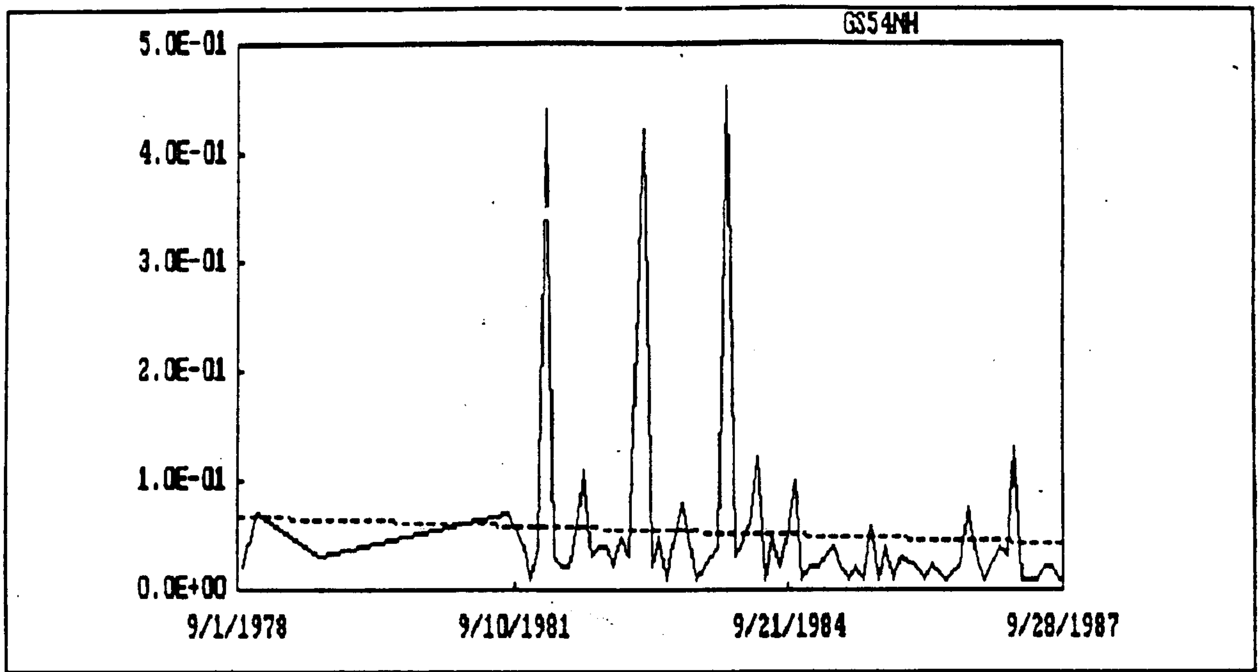

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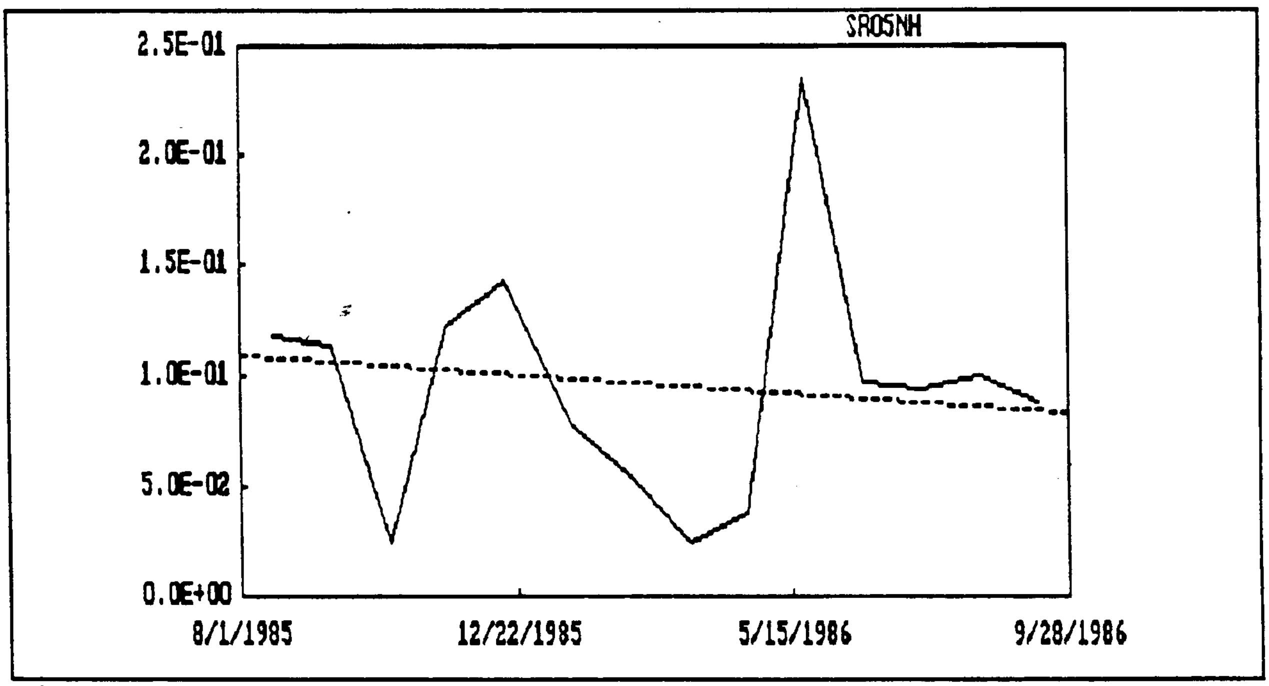
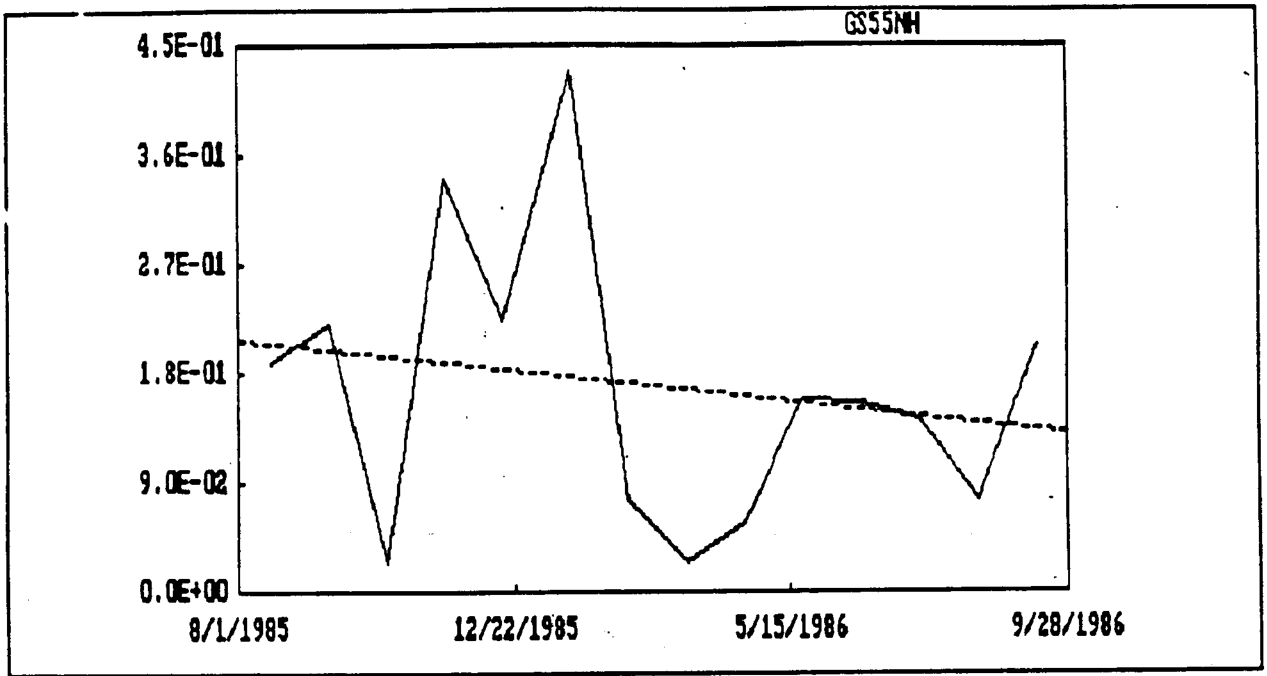


Figure H-4. Ammonia (as n) time series plot of monthly average concentration in mg/l at SR 0.5. Seasonal Kendall Sen Slope Estimate = -0.022 mg/l/yr.



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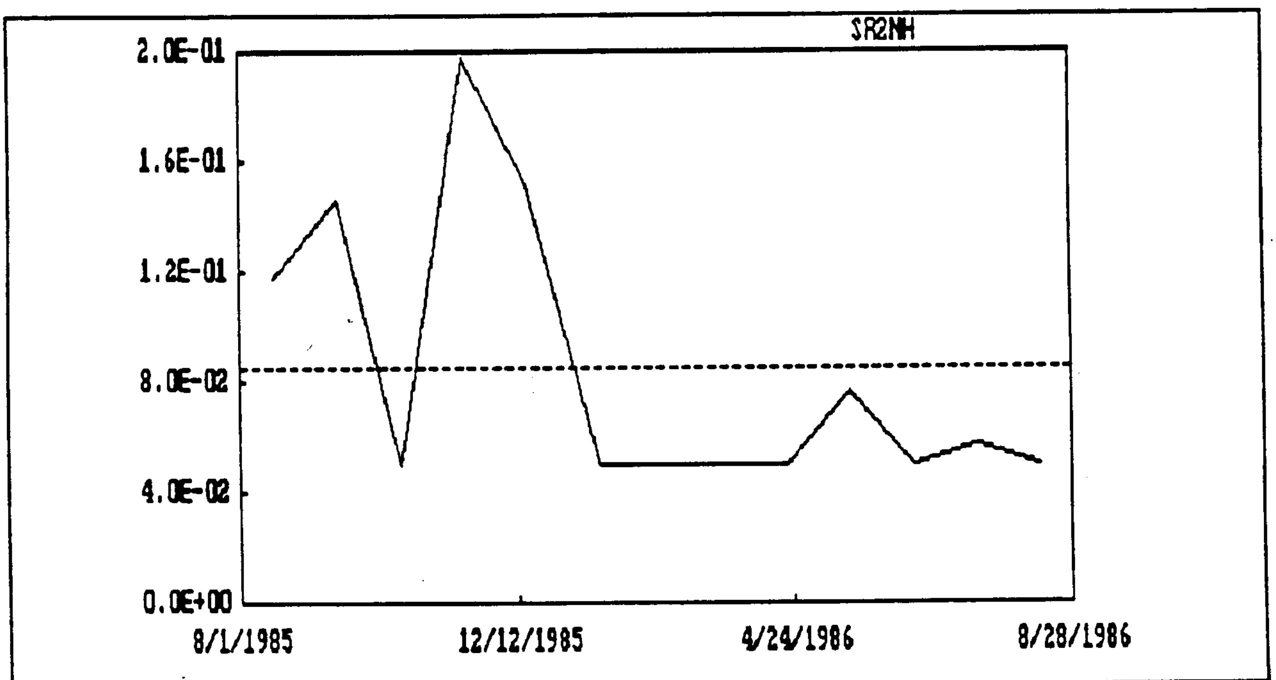

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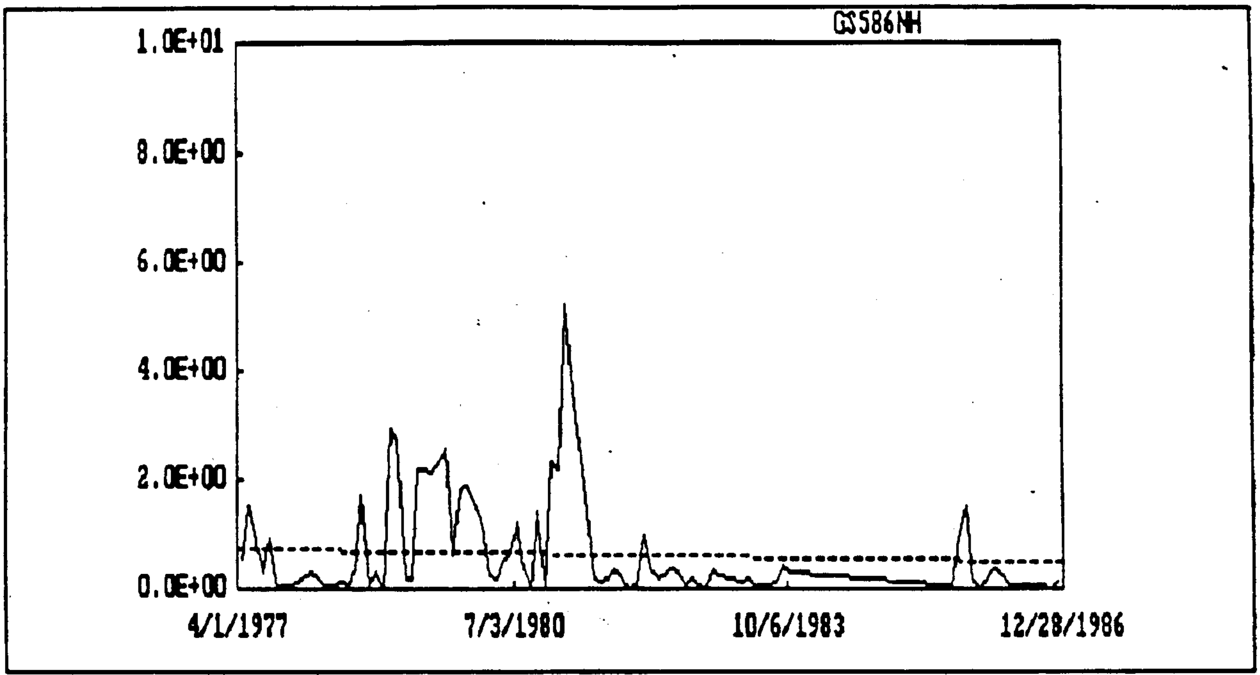

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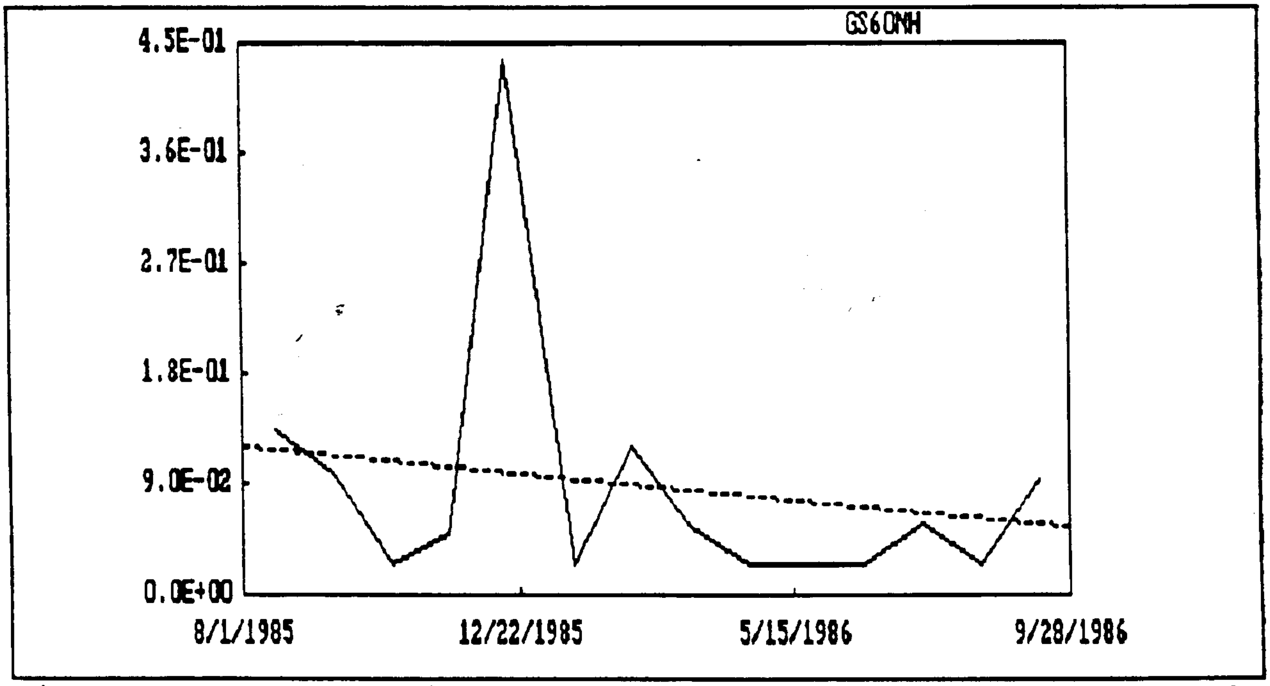

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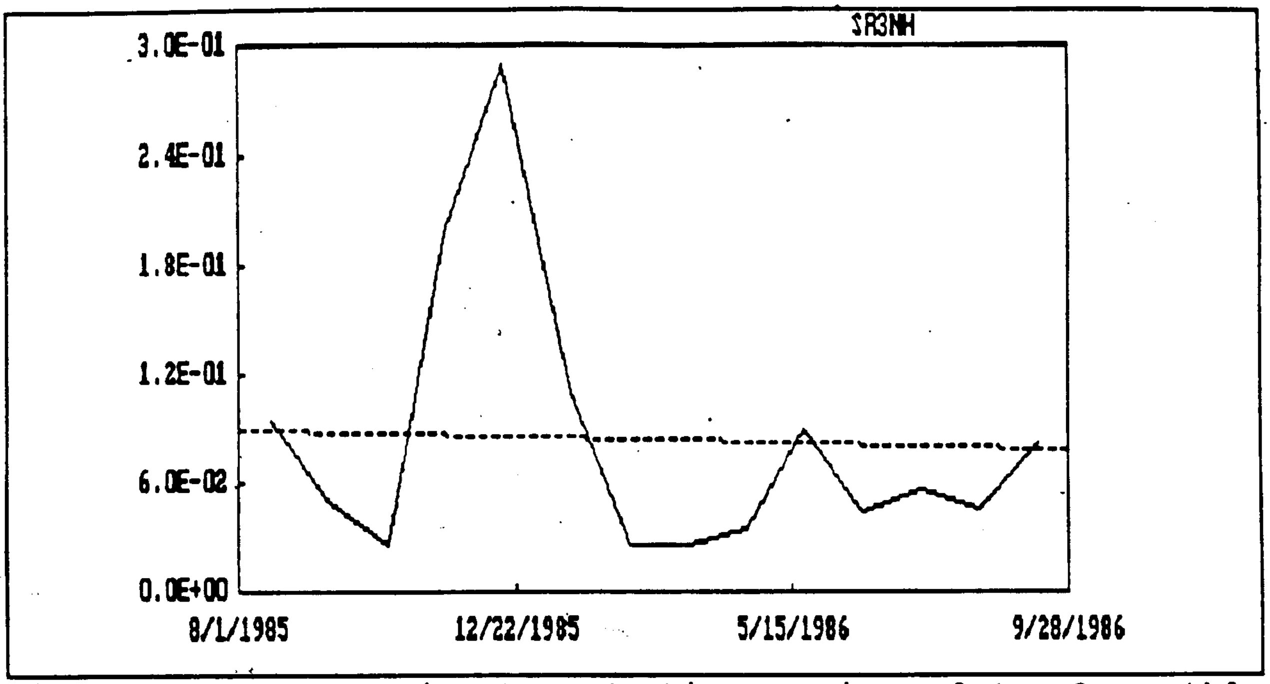

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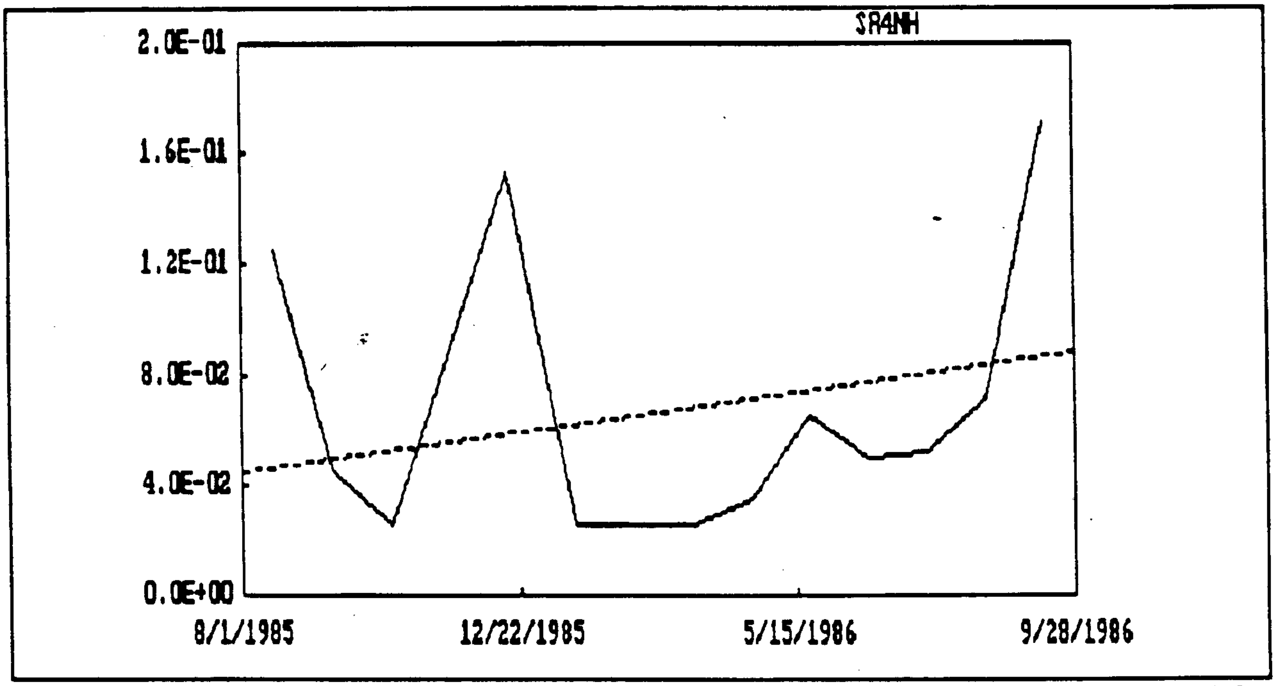

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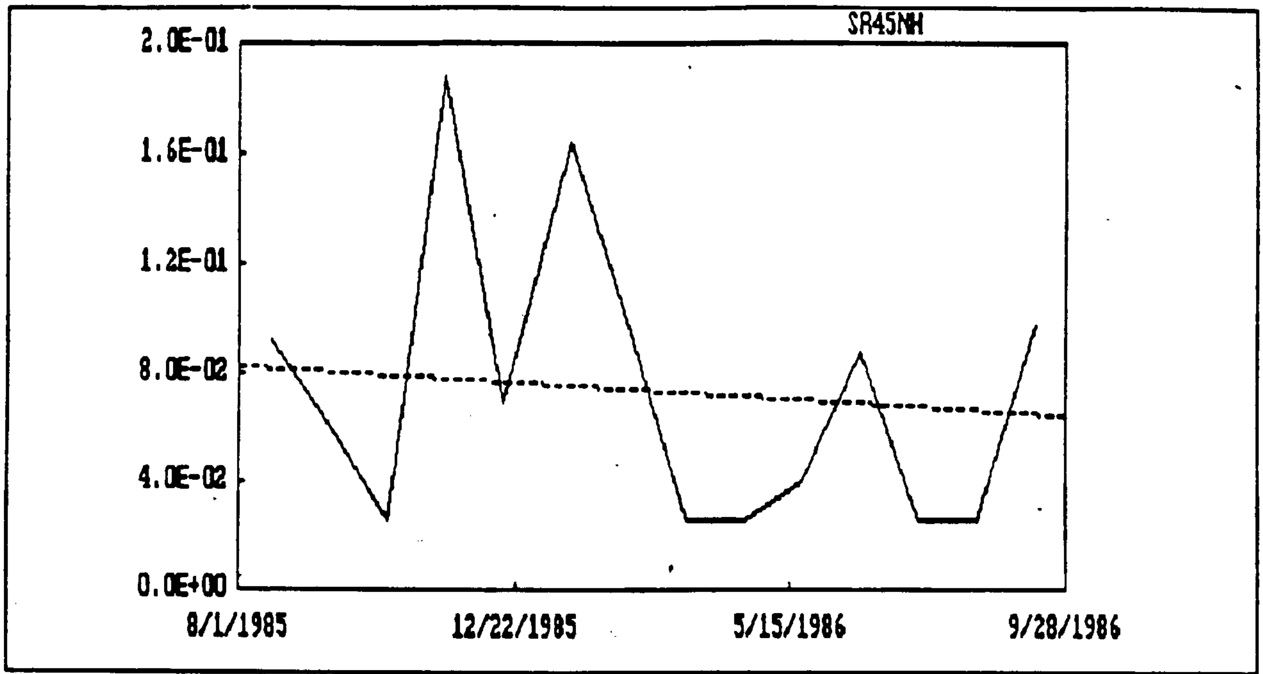

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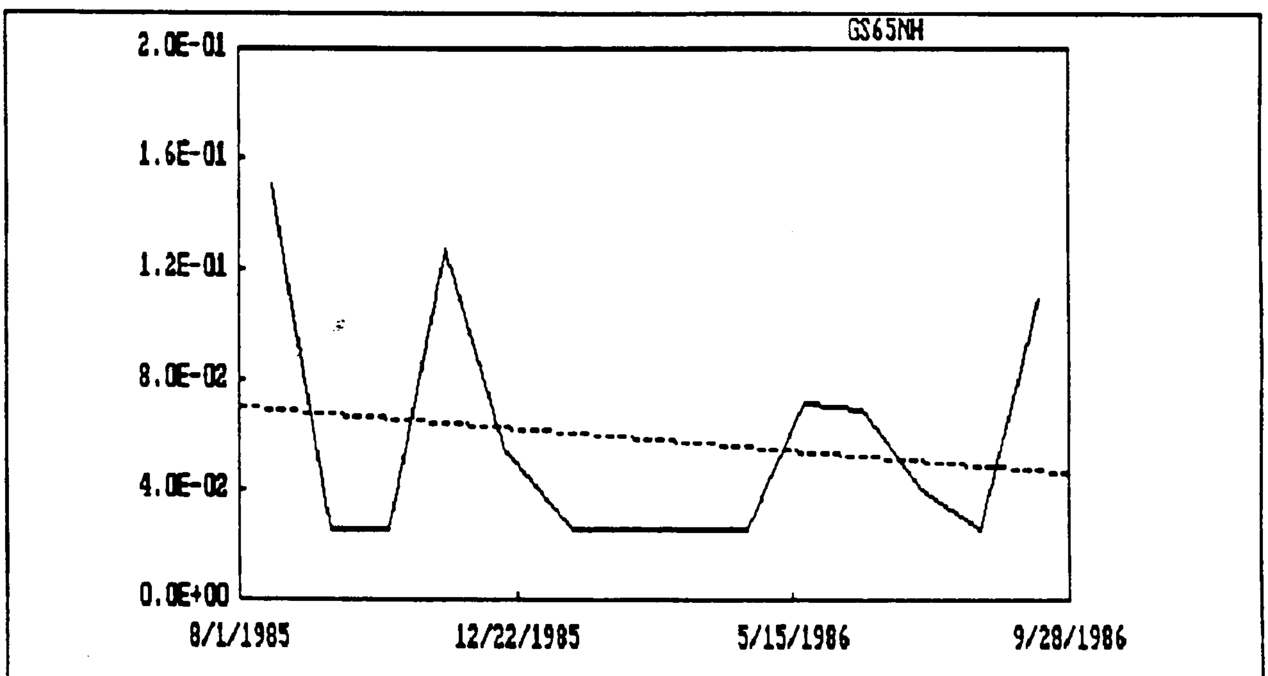

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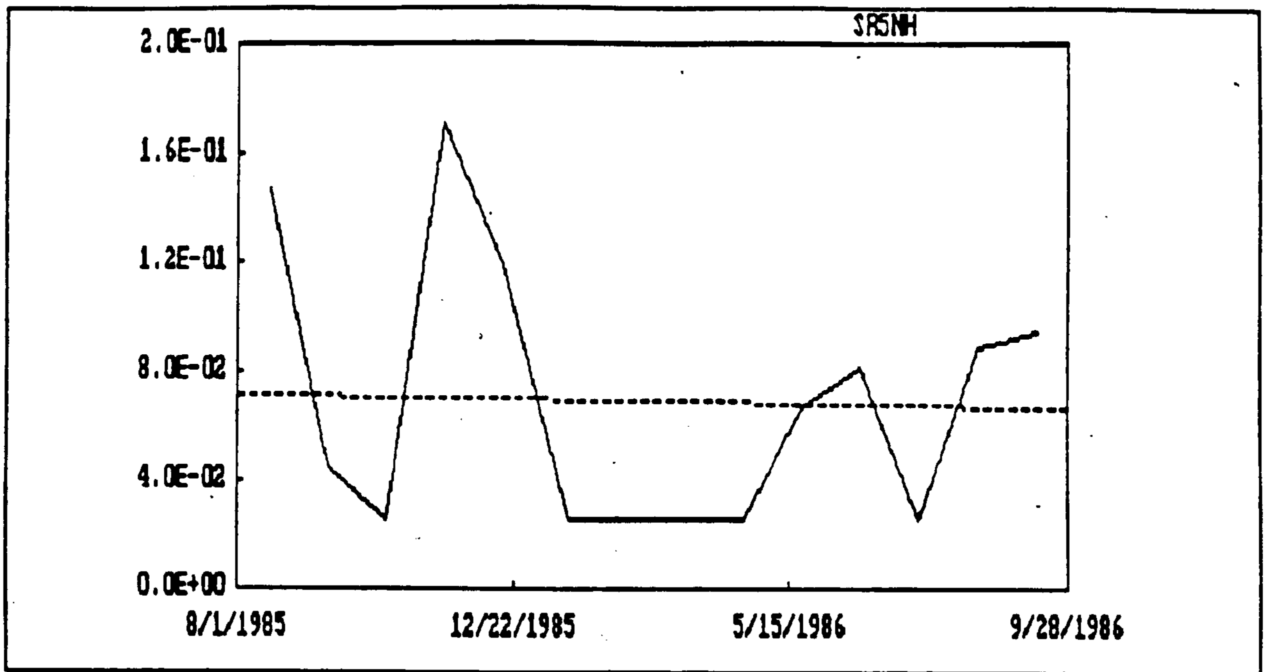
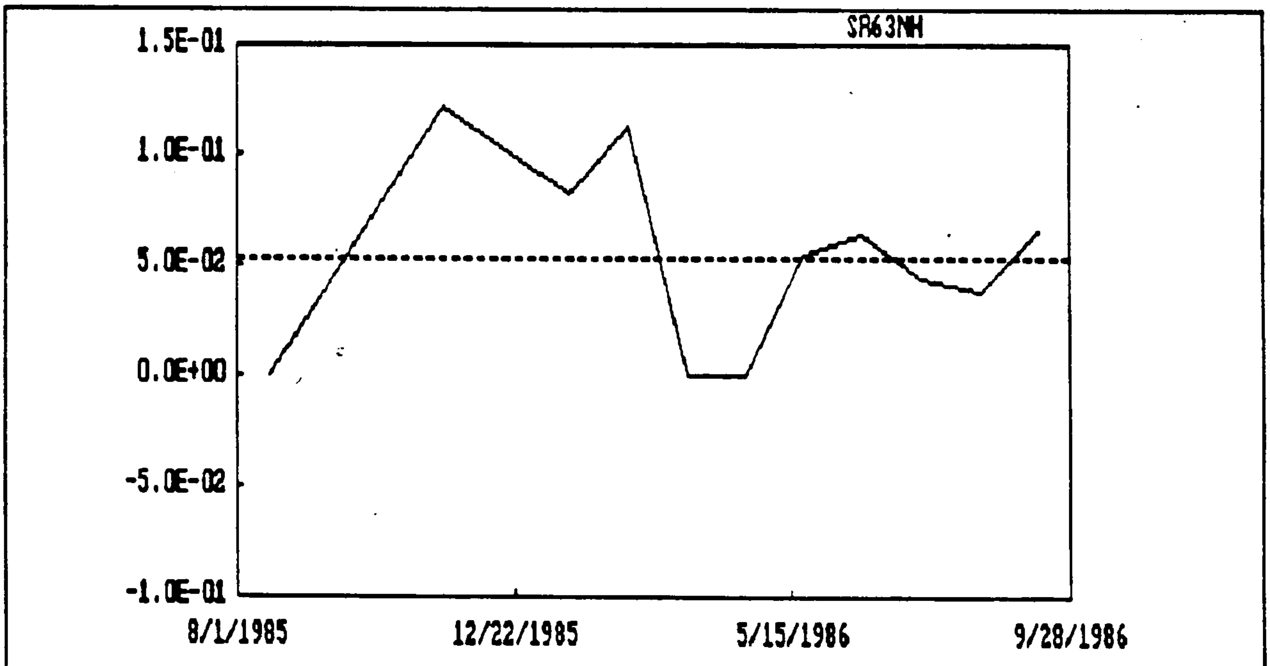


Figure H-12. Ammonia (as n) time series plot of monthly average concentration in mg/l at SR 5. Seasonal Kendall Sen Slope Estimate = -0.004 mg/l/yr.



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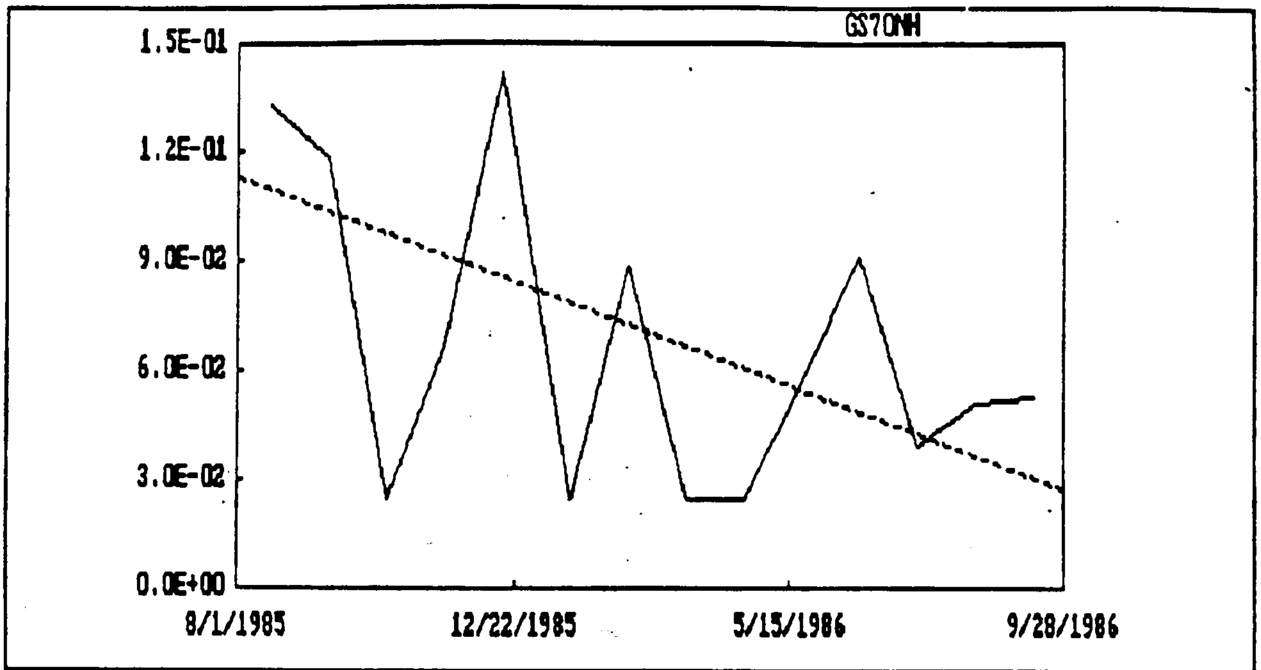

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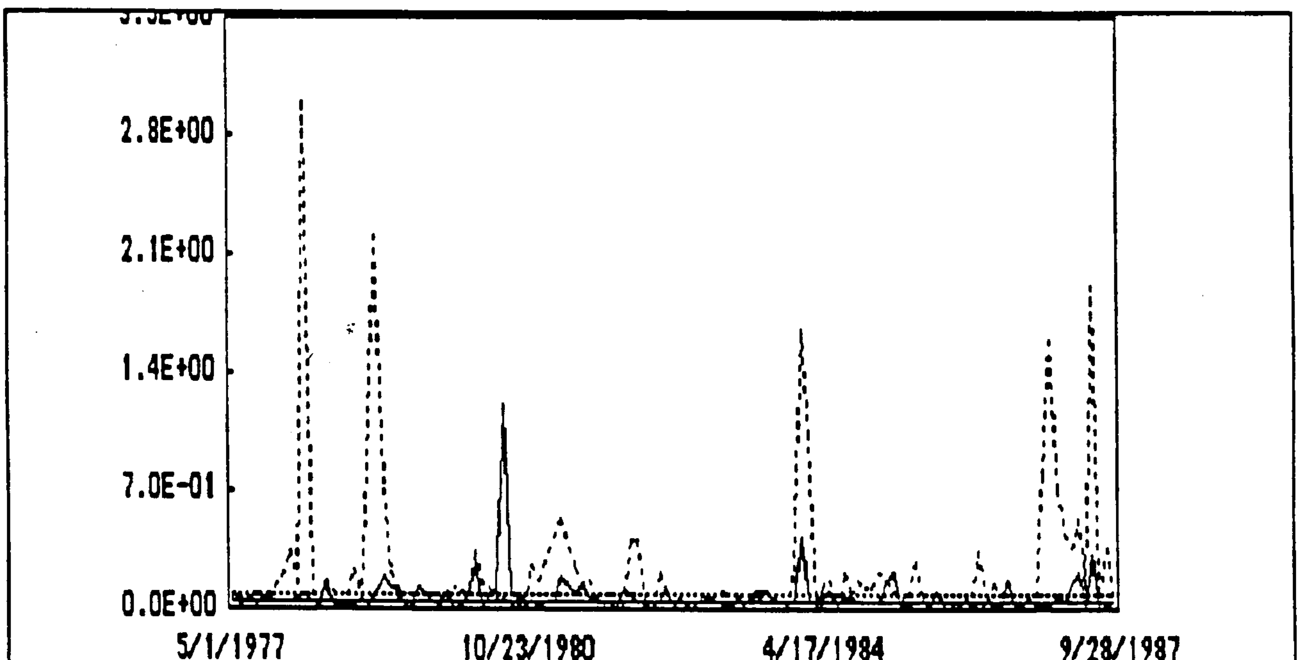
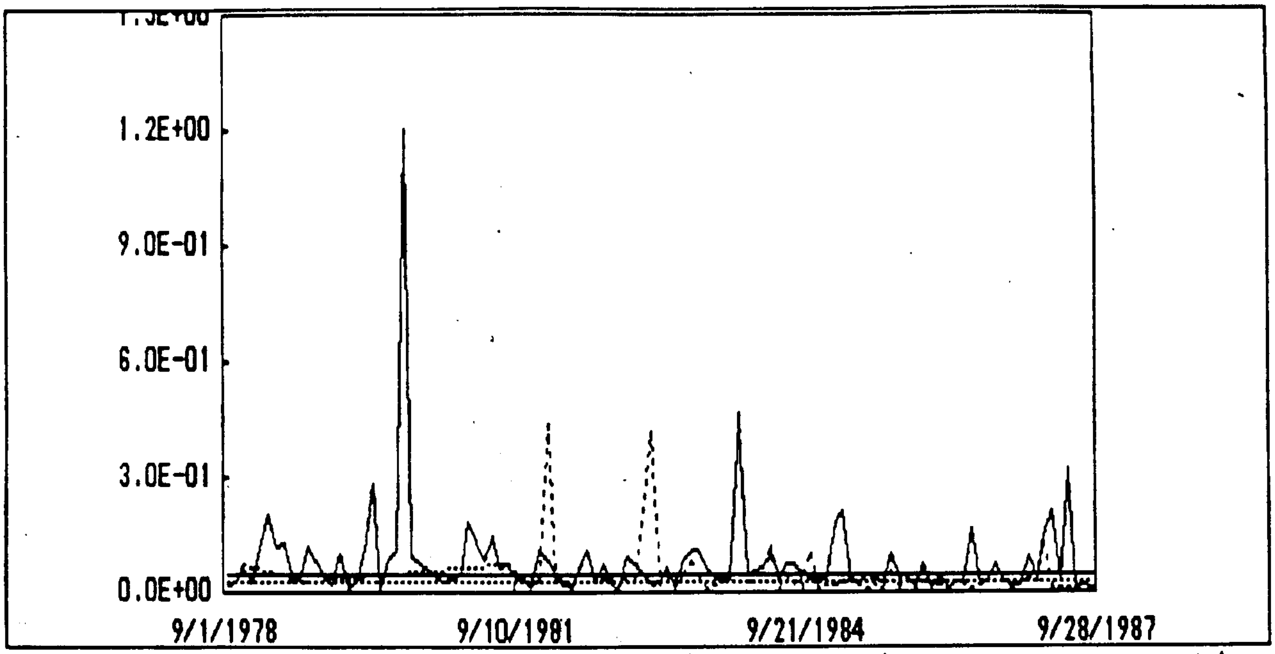


Figure H-16. Comparison of median ammonia(N) concentration (mg/l) at USGS 07194800 (solid line) vs USGS 07195000 (dashed line) using the Wilcoxon signed rank test.



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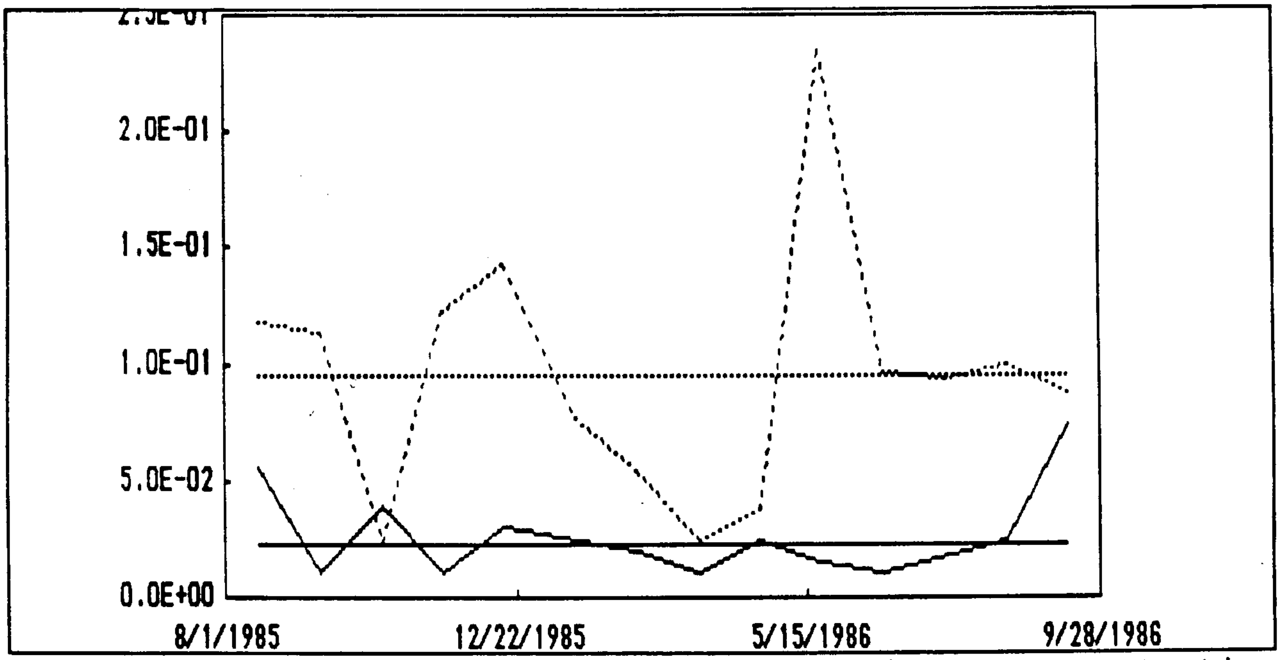

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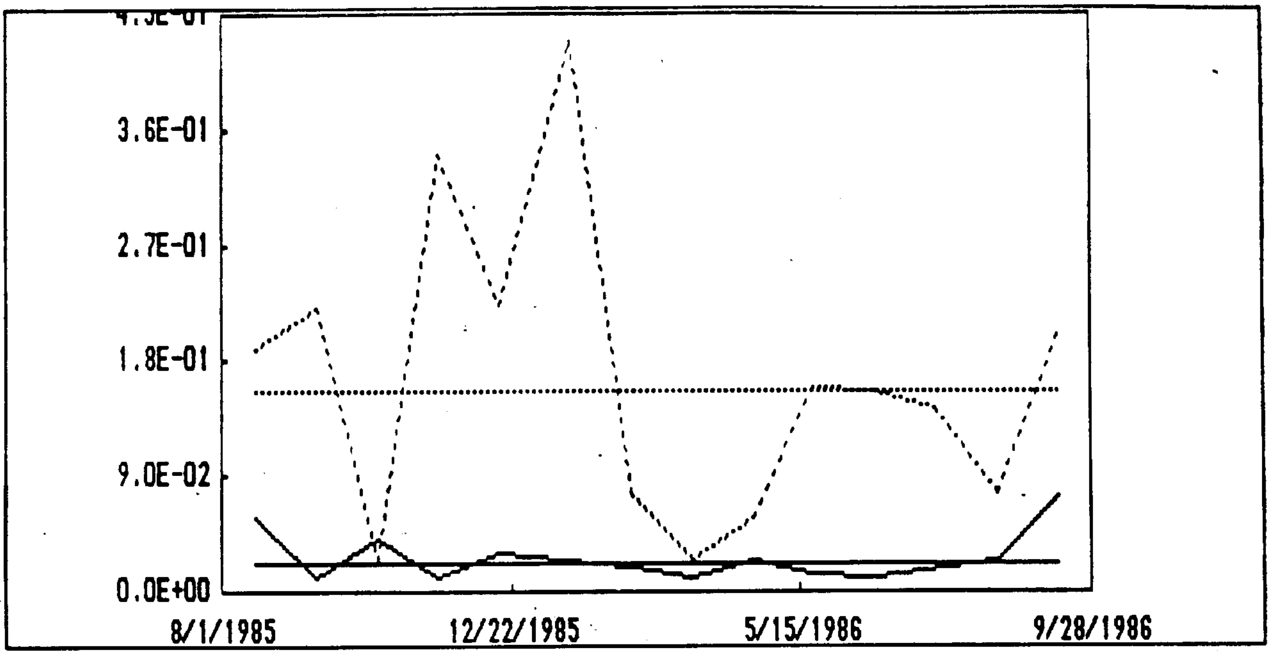

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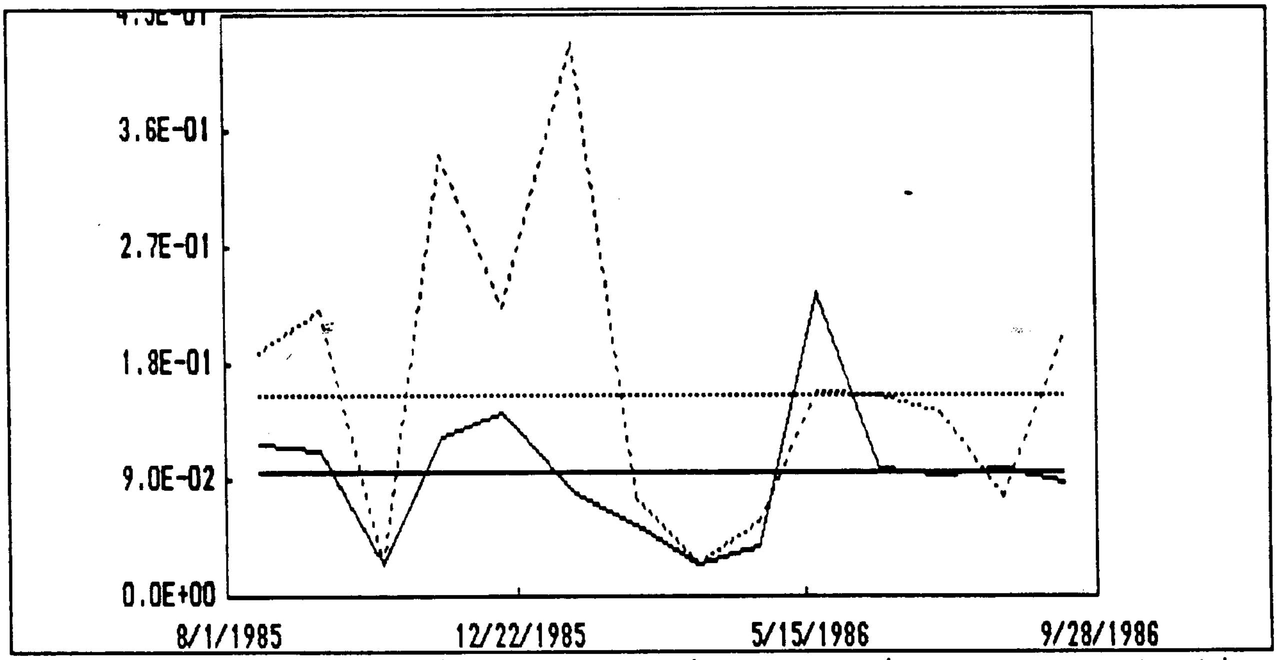

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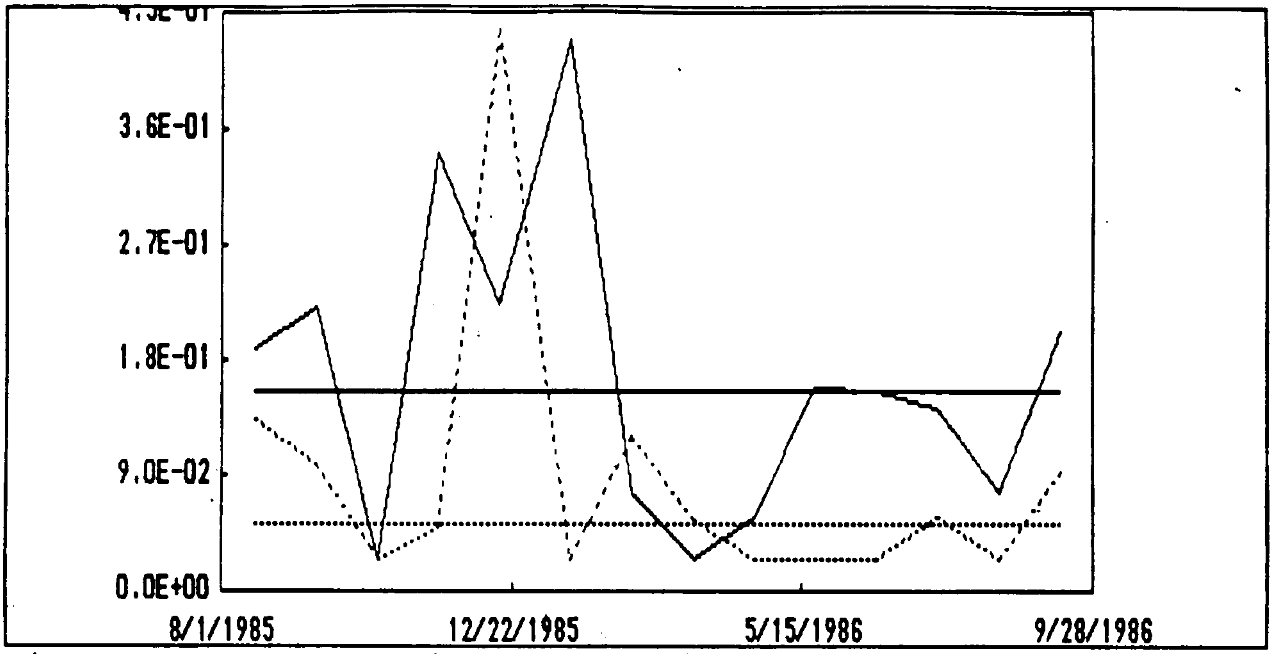

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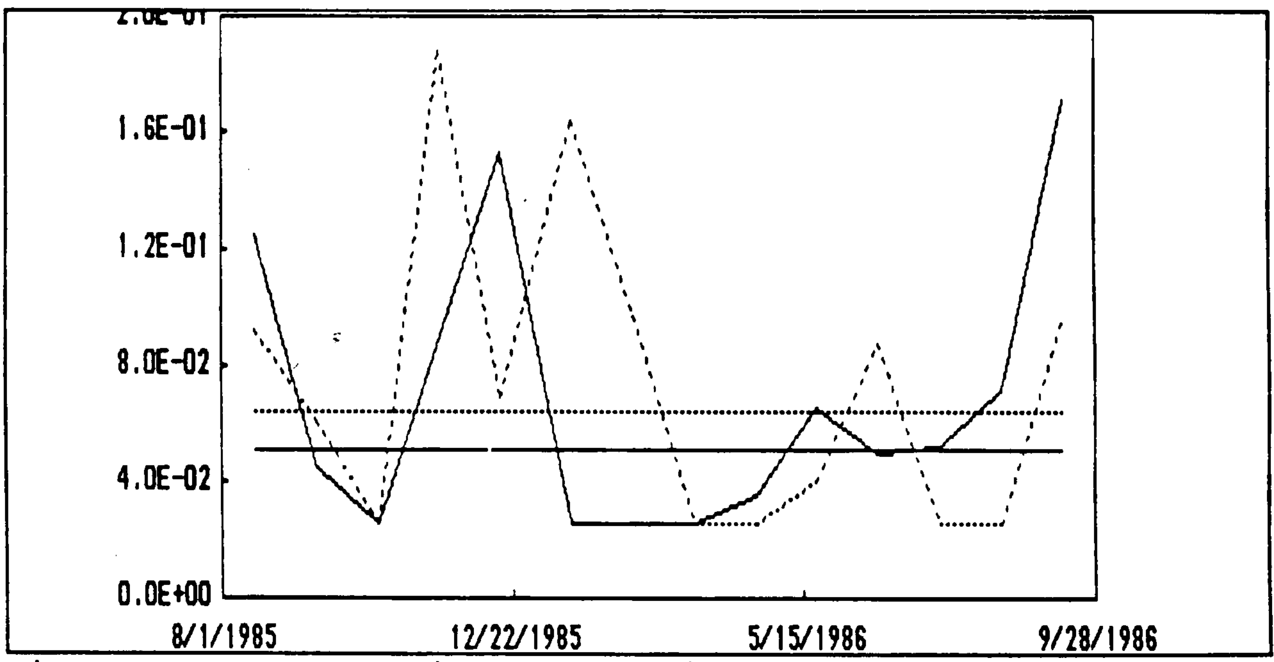

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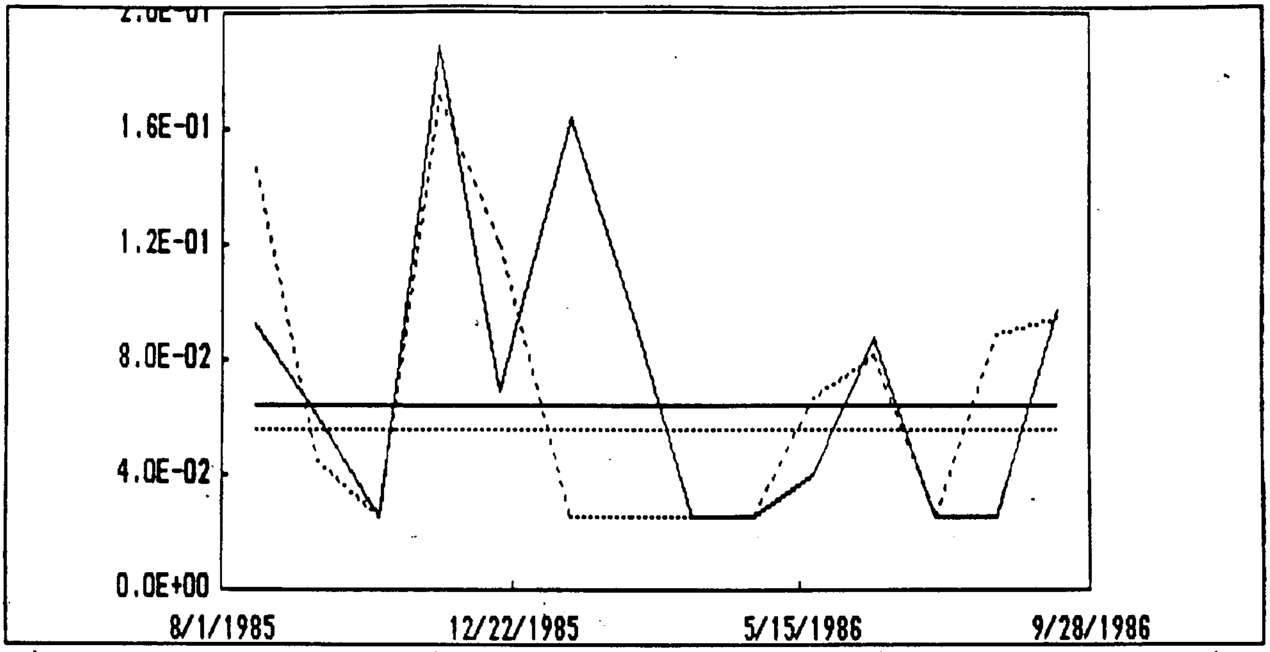

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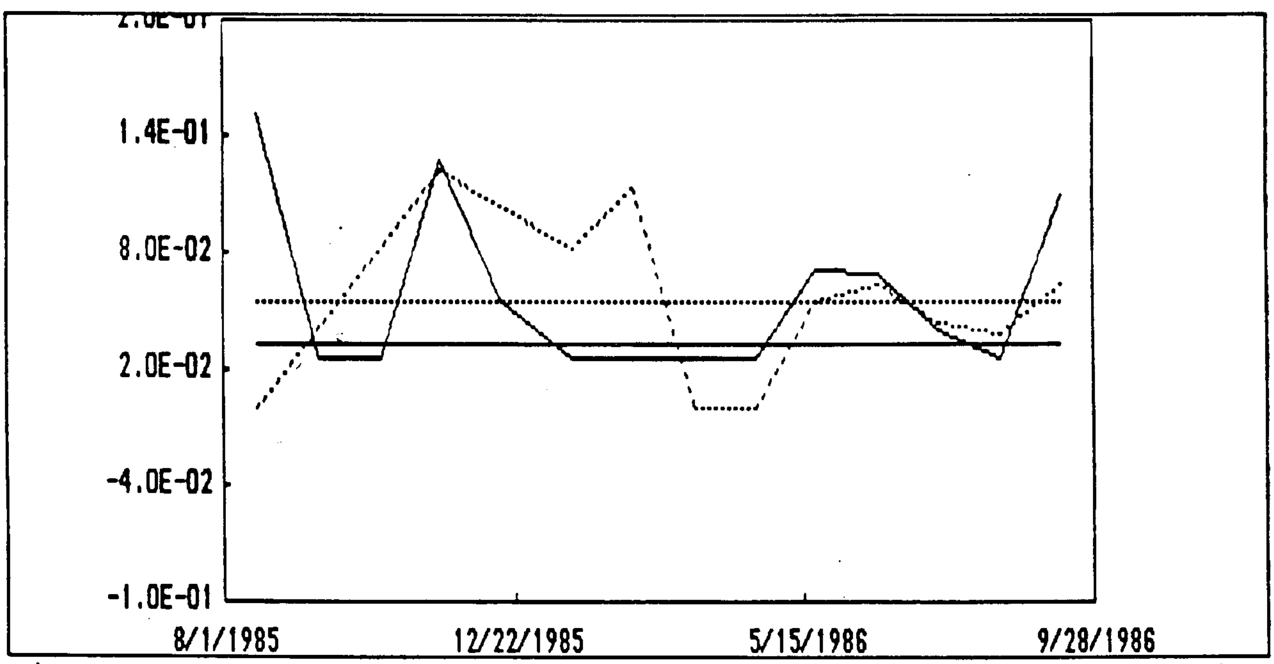

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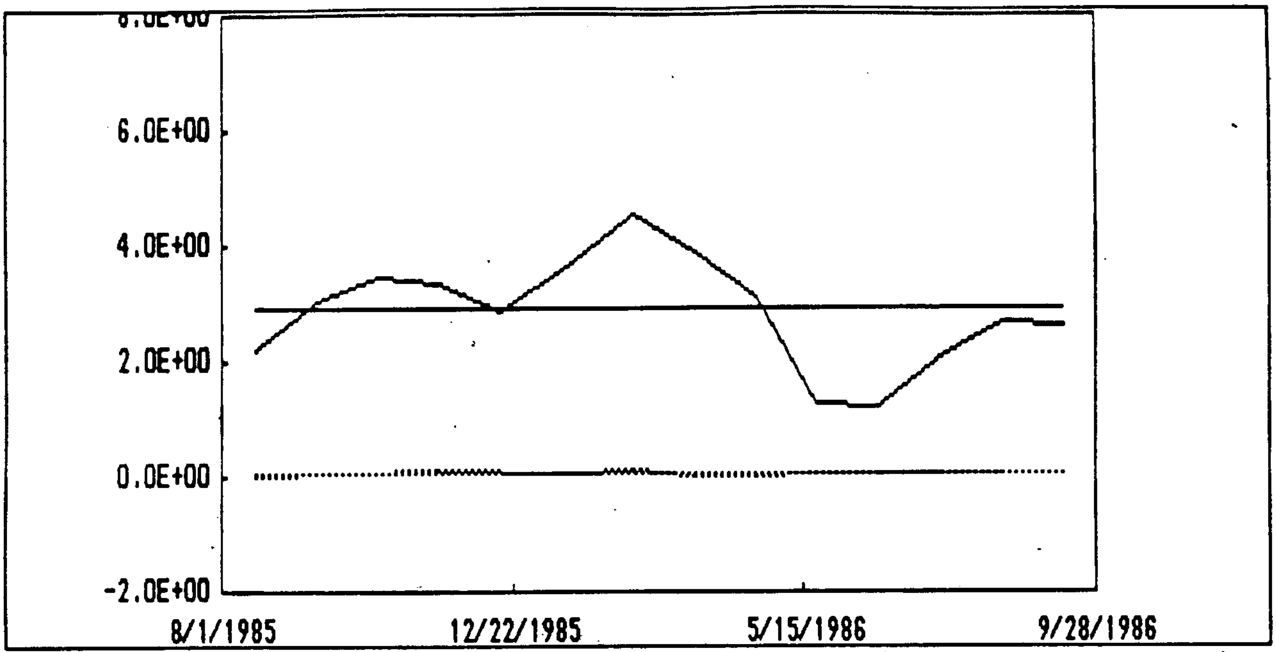

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APPENDIX I

GRAPHIC ILLUSTRATION OF LONG TERM TEMPORAL TRENDS AND COMPARISON OF MEDIAN TURBIDITY CONCENTRATION OF UPSTREAM VS DOWNSTREAM STATIONS ALONG THE ILLINOIS RIVER

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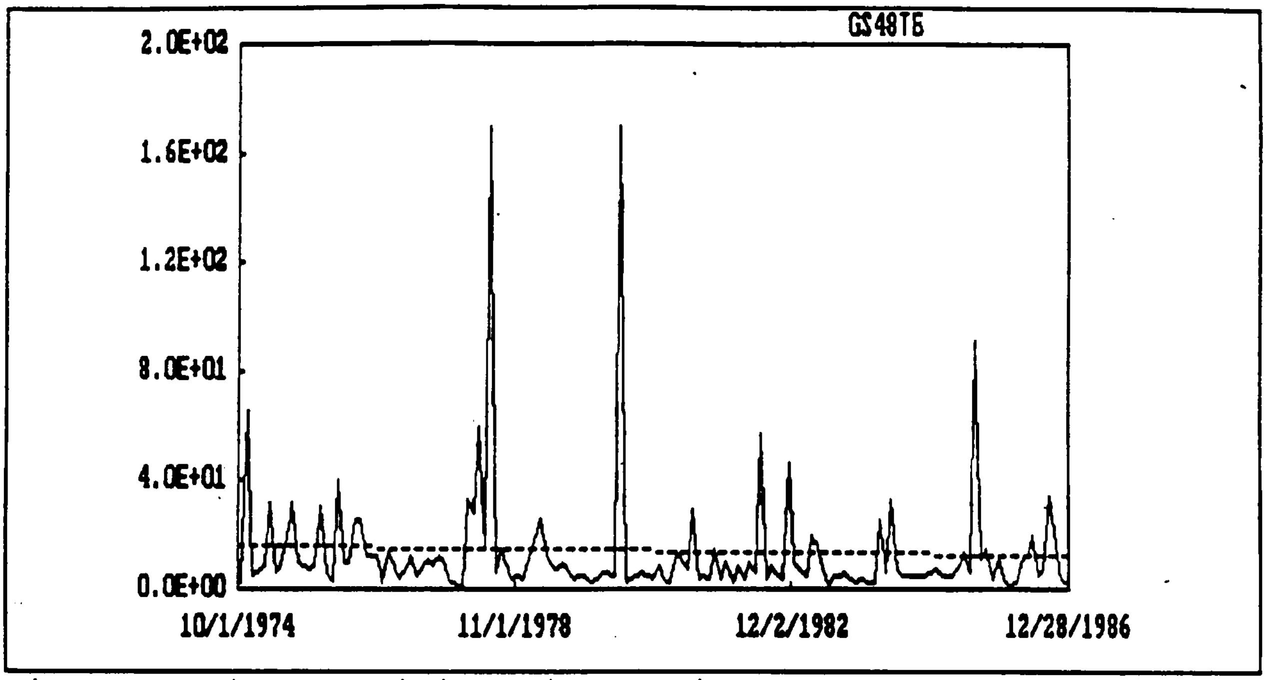
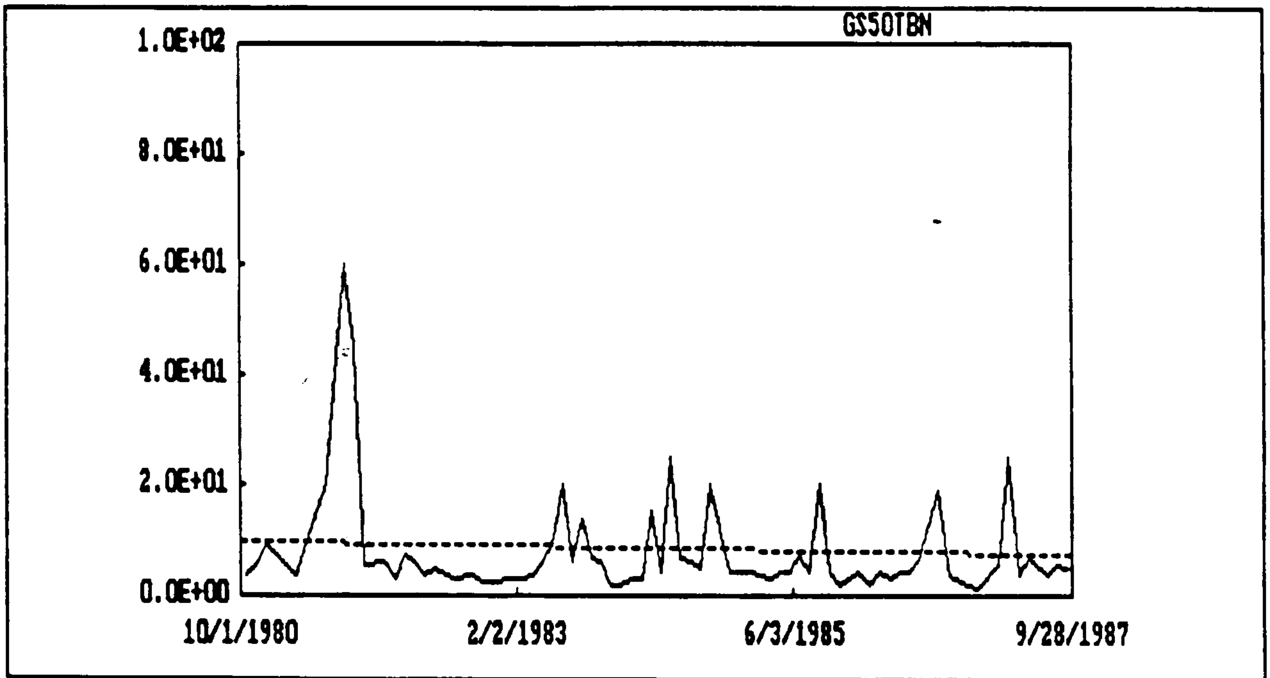


Figure I-1. Turbidity time series plot of monthly average levels in JTUs at USGS 07194800. Seasonal Kendall Sen Slope Estimate = -0.250 JTU/yr.



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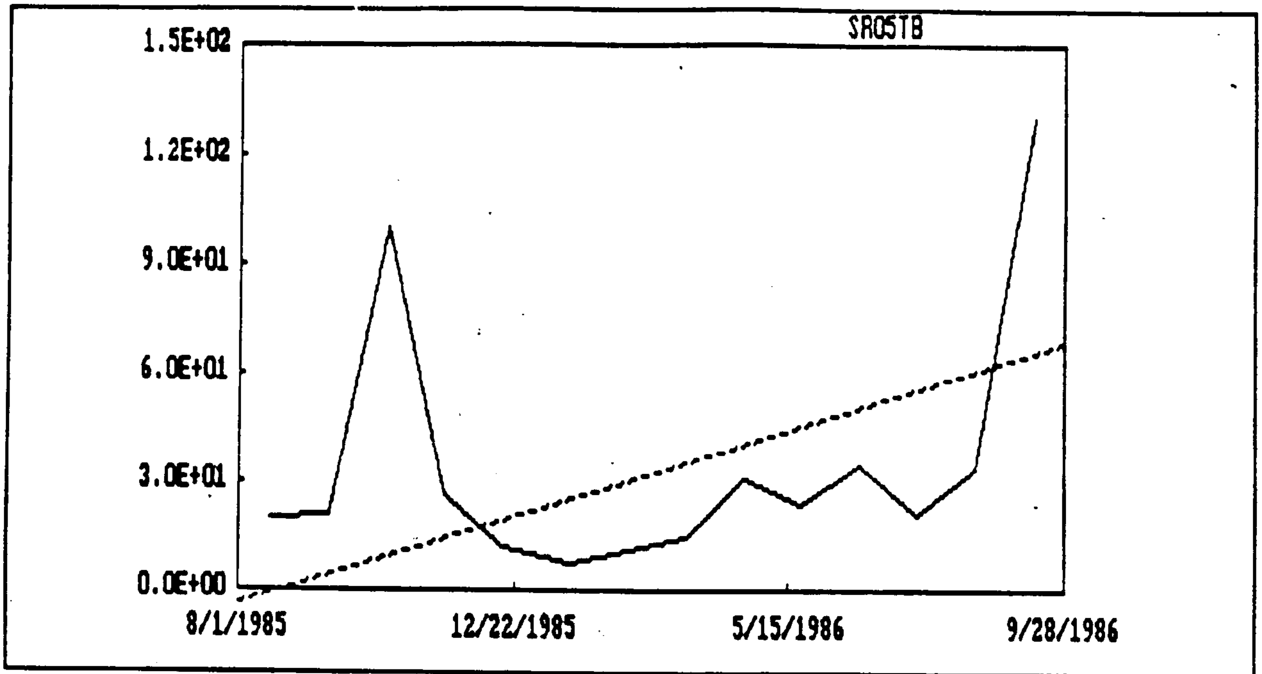

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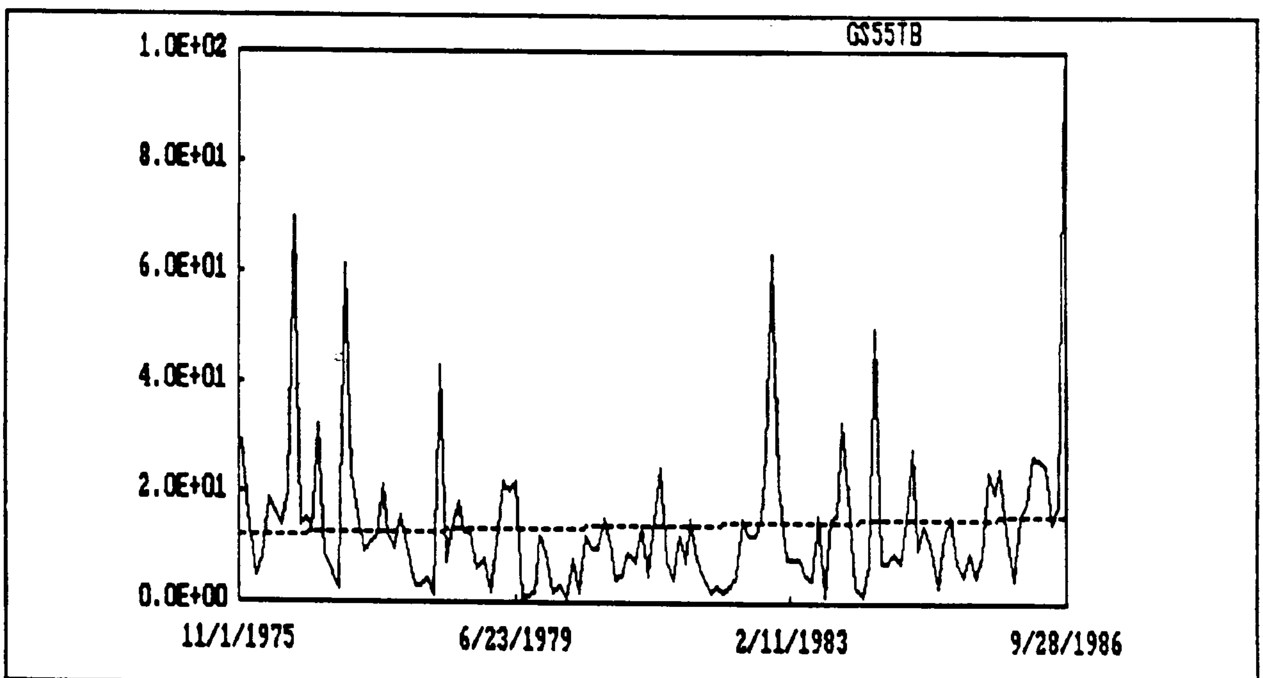

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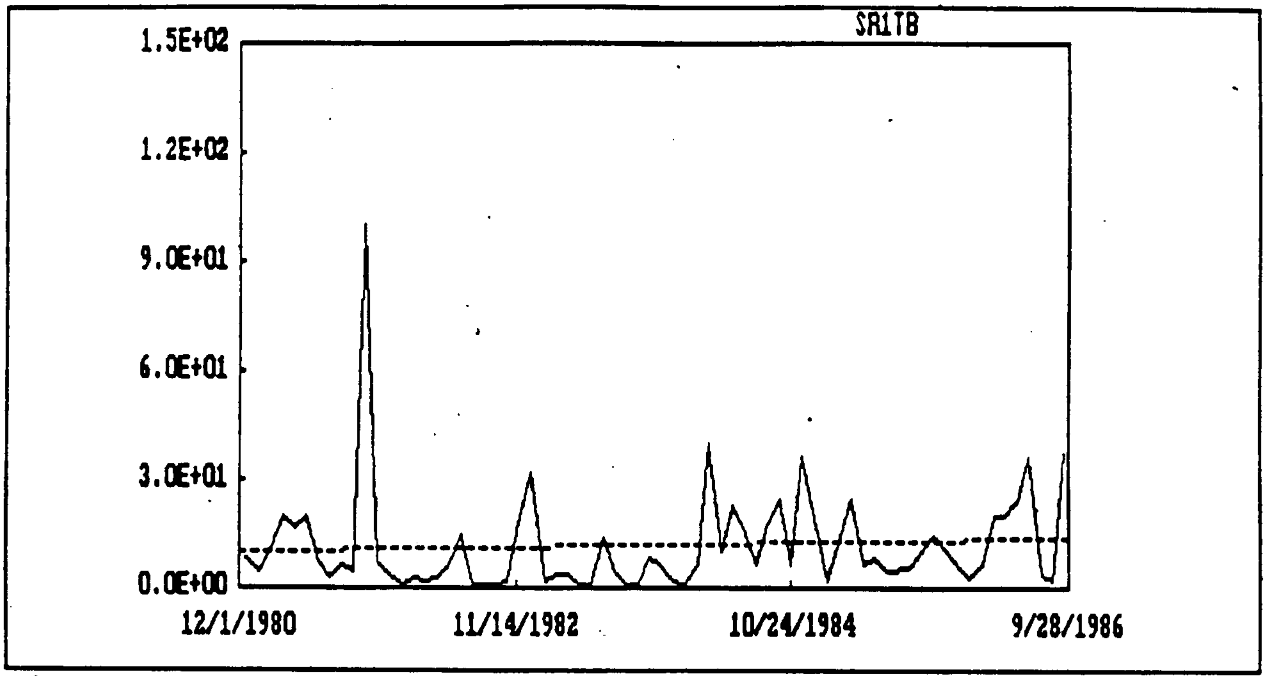

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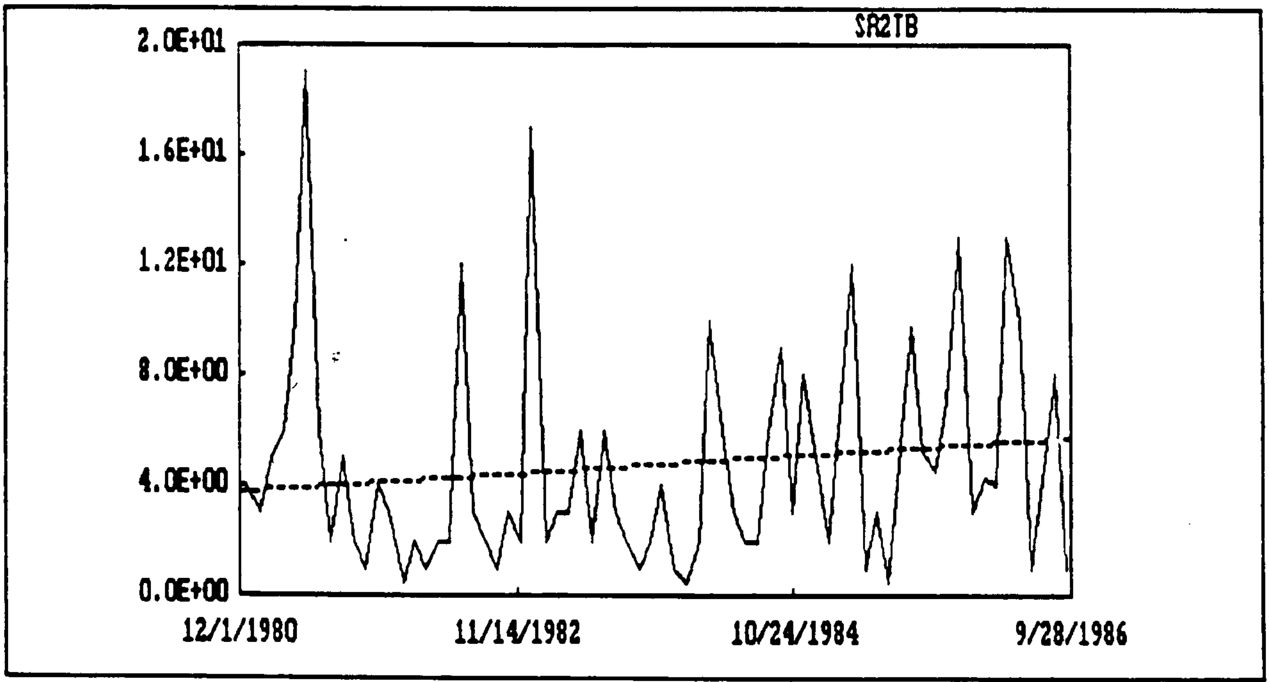

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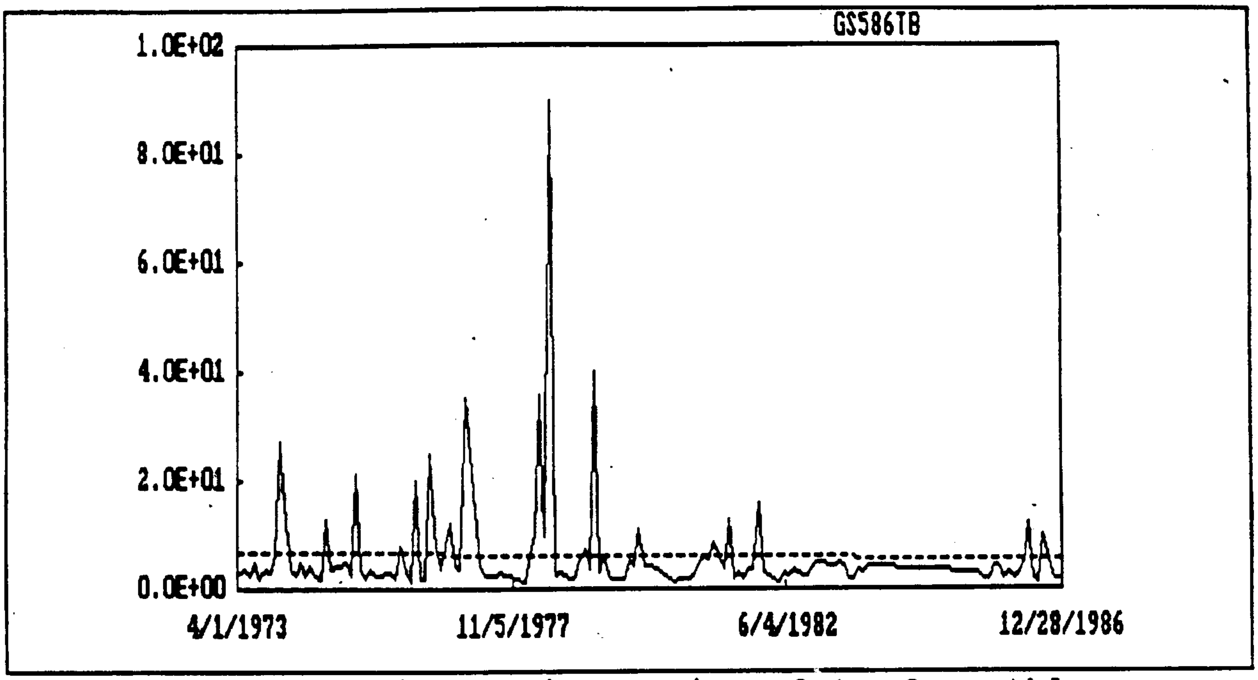

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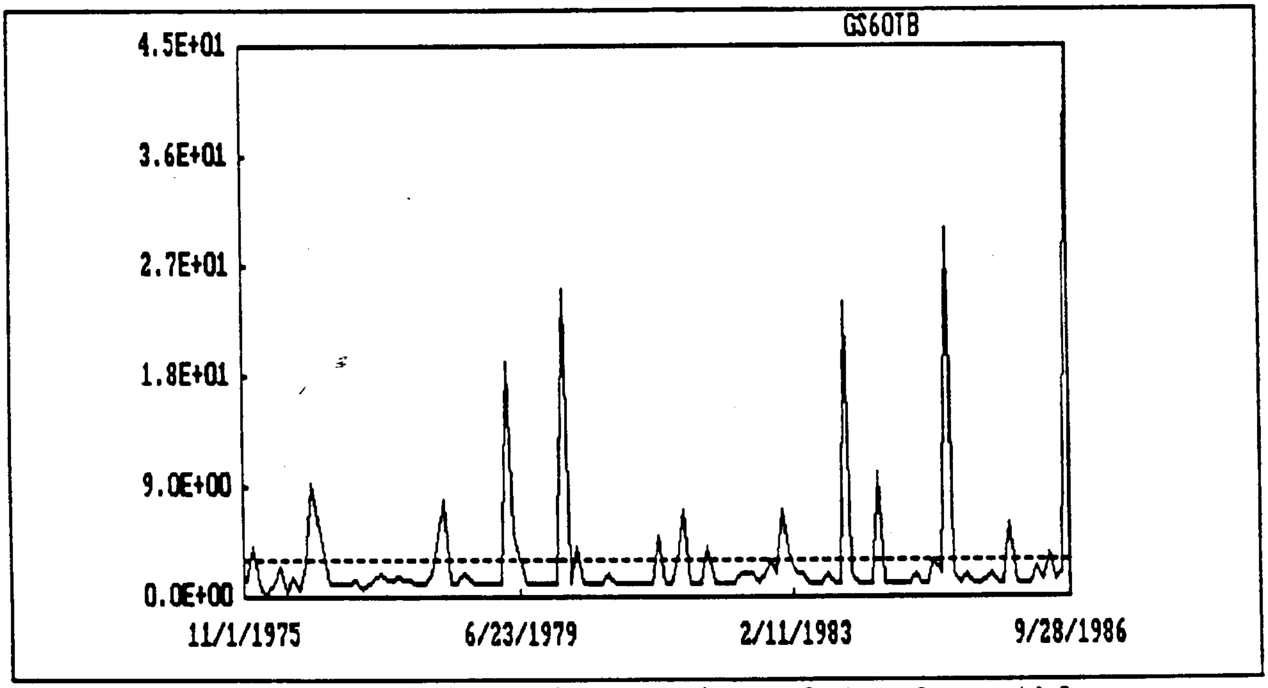

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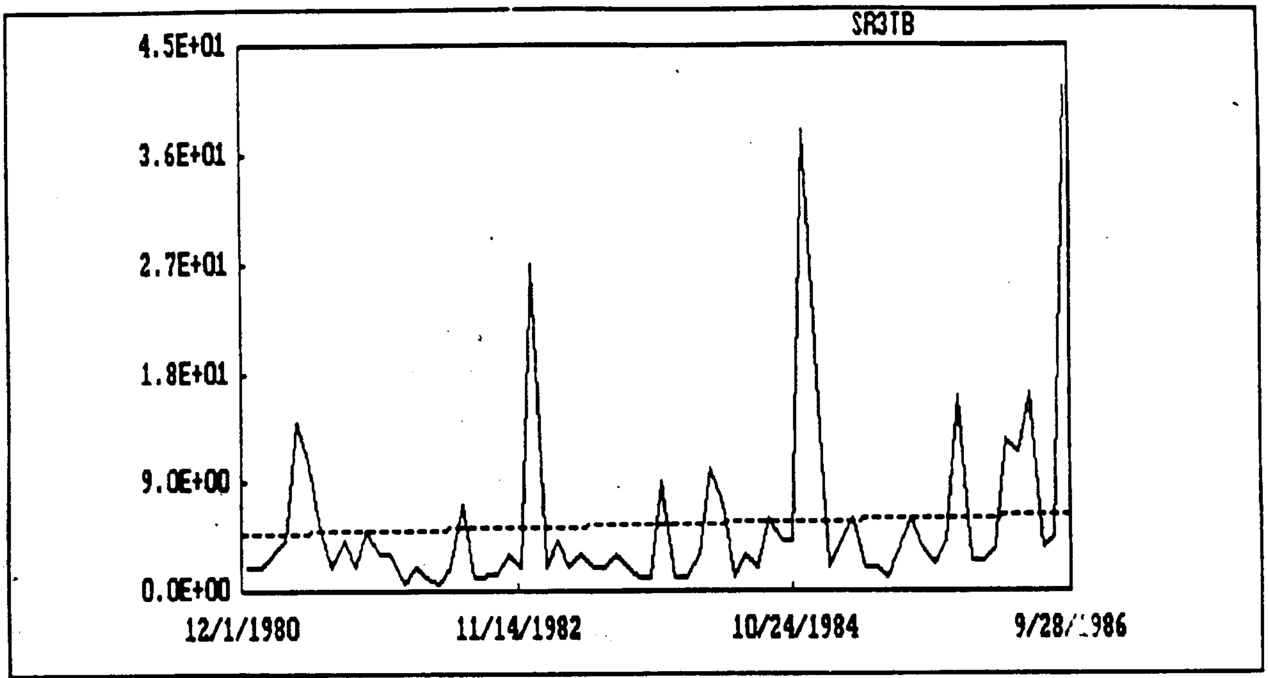

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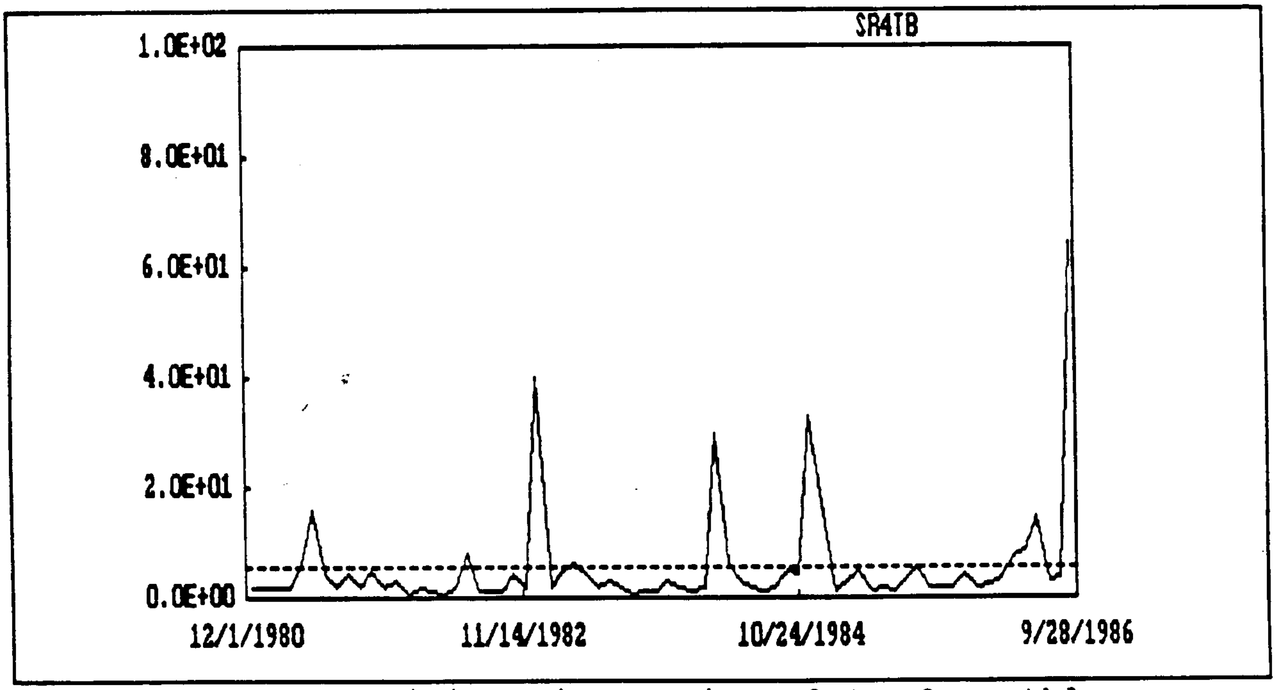


Figure I-10. Turbidity time series plot of monthly average levels in JTUs at SR 4. Seasonal Kendall Sen Slope Estimate = 0.050 JTU/yr.

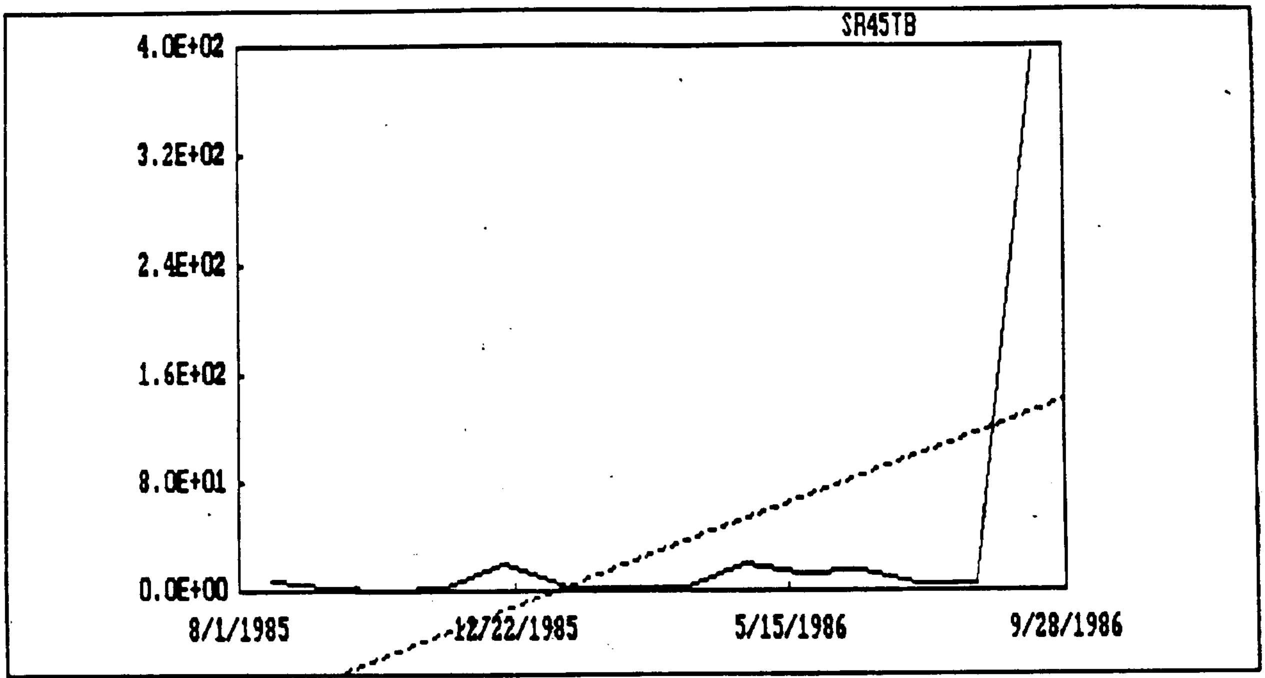


Figure I-11. Turbidity time series plot of monthly average levels in JTUs at SR 4.5. Seasonal Kendall Sen Slope Estimate = 195.417 JTU/yr.

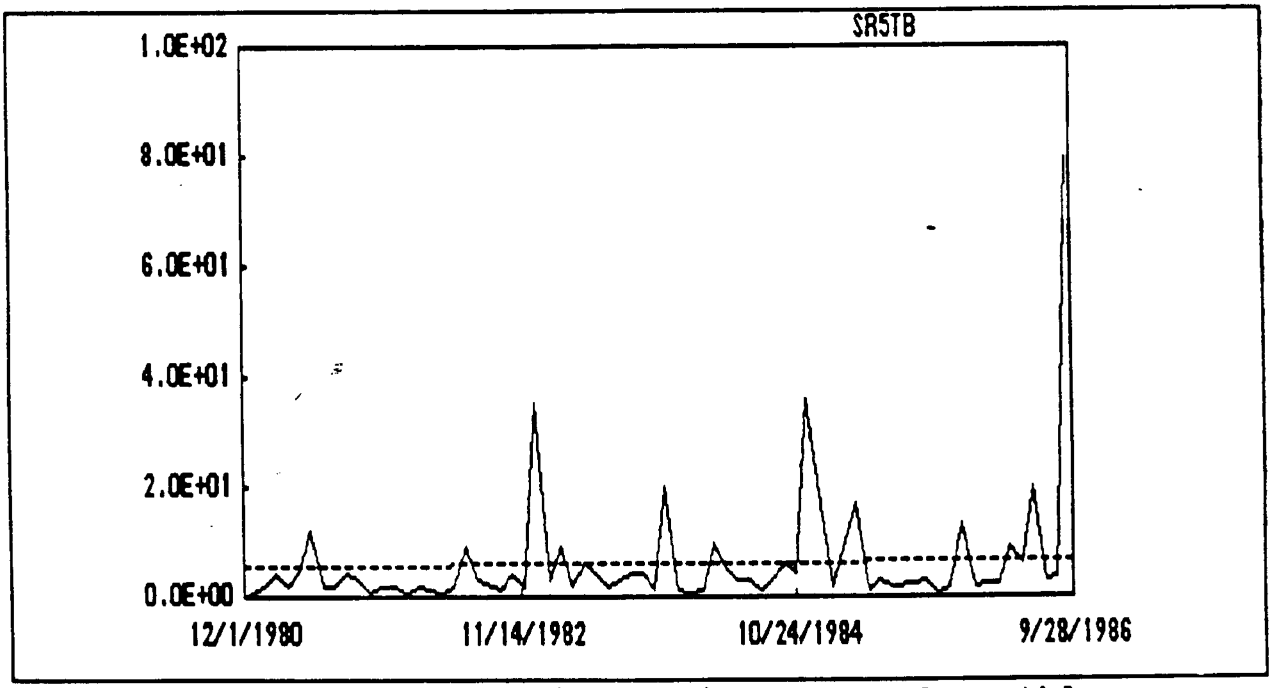
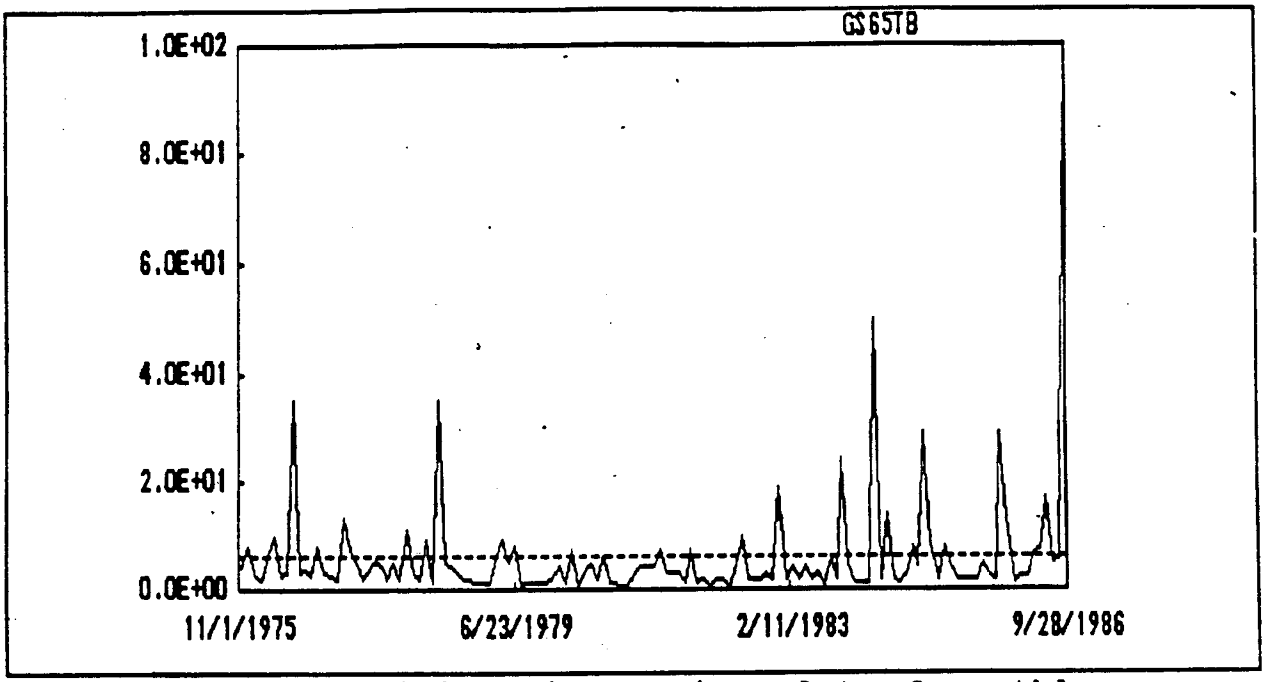


Figure I-12. Turbidity time series plot of monthly average levels in JTUs at SR 5. Seasonal Kendall Sen Slope Estimate = 0.167 JTU/yr.



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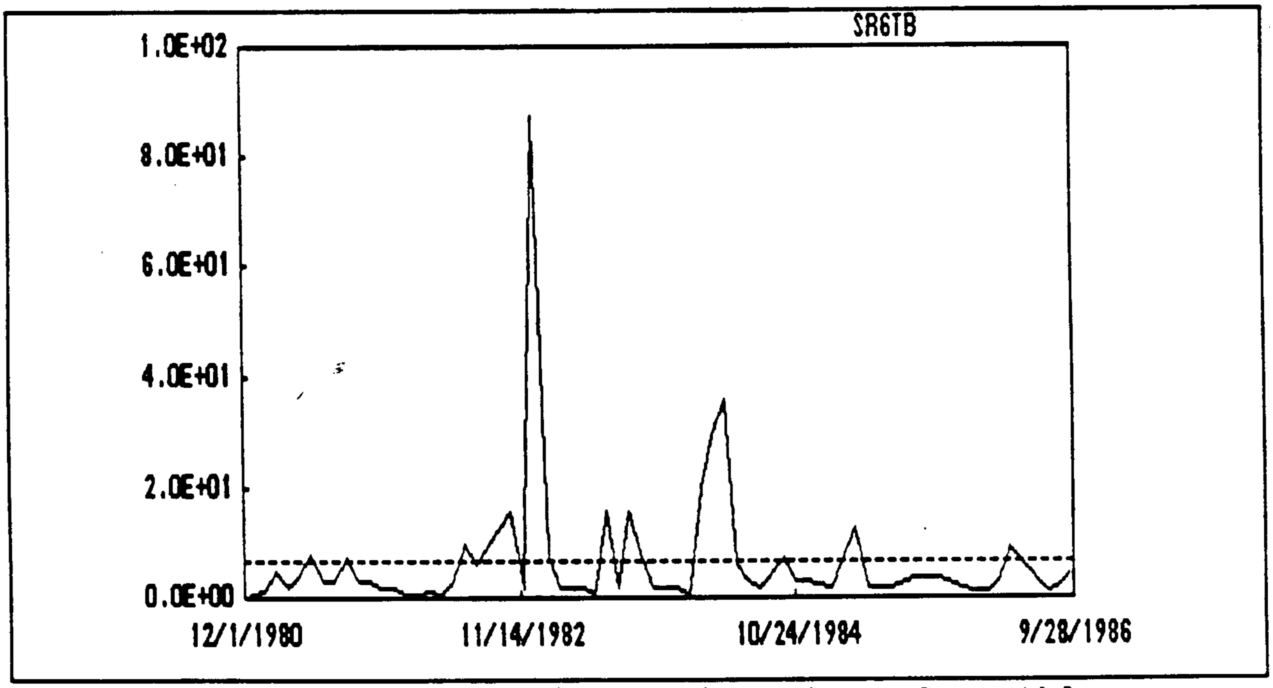


Figure I-14. Turbidity time series plot of monthly average levels in JTUs at SR 6. Seasonal Kendall Sen Slope Estimate = 0.000 JTU/yr.

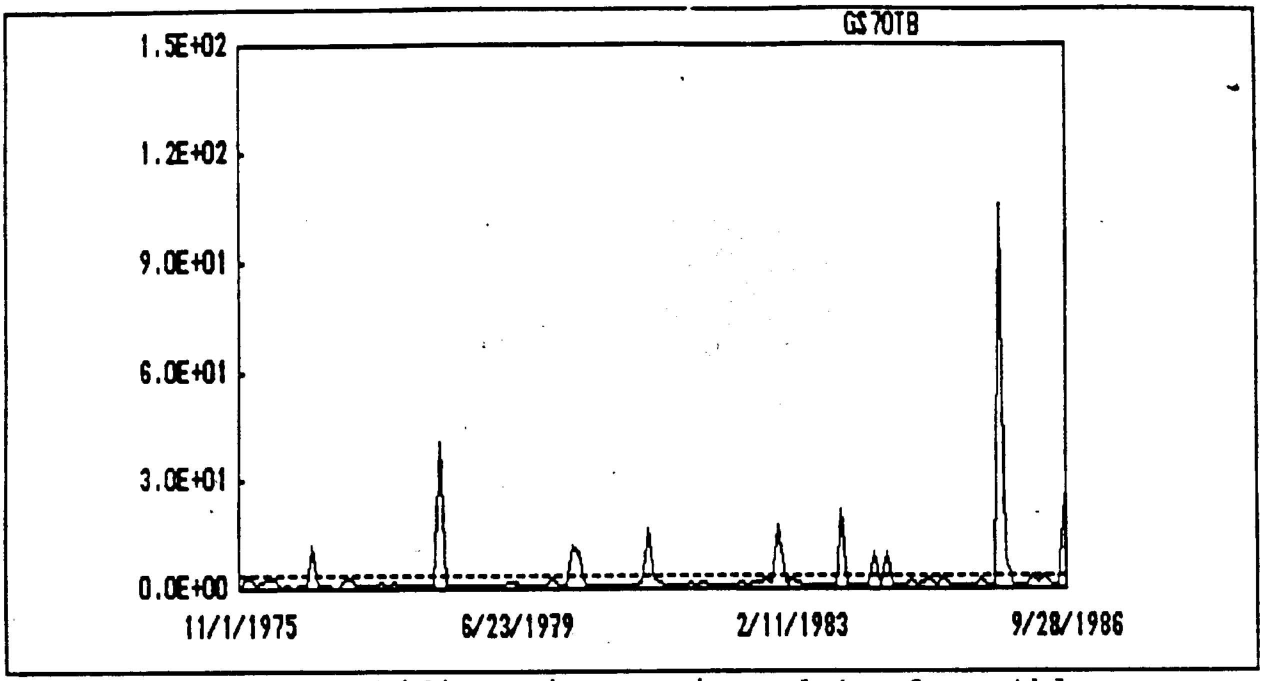


Figure I-15. Turbidity time series plot of monthly average levels in JTUs at USGS 07197000. Seasonal Kendall Sen Slope Estimate = 0.015 JTU/yr.

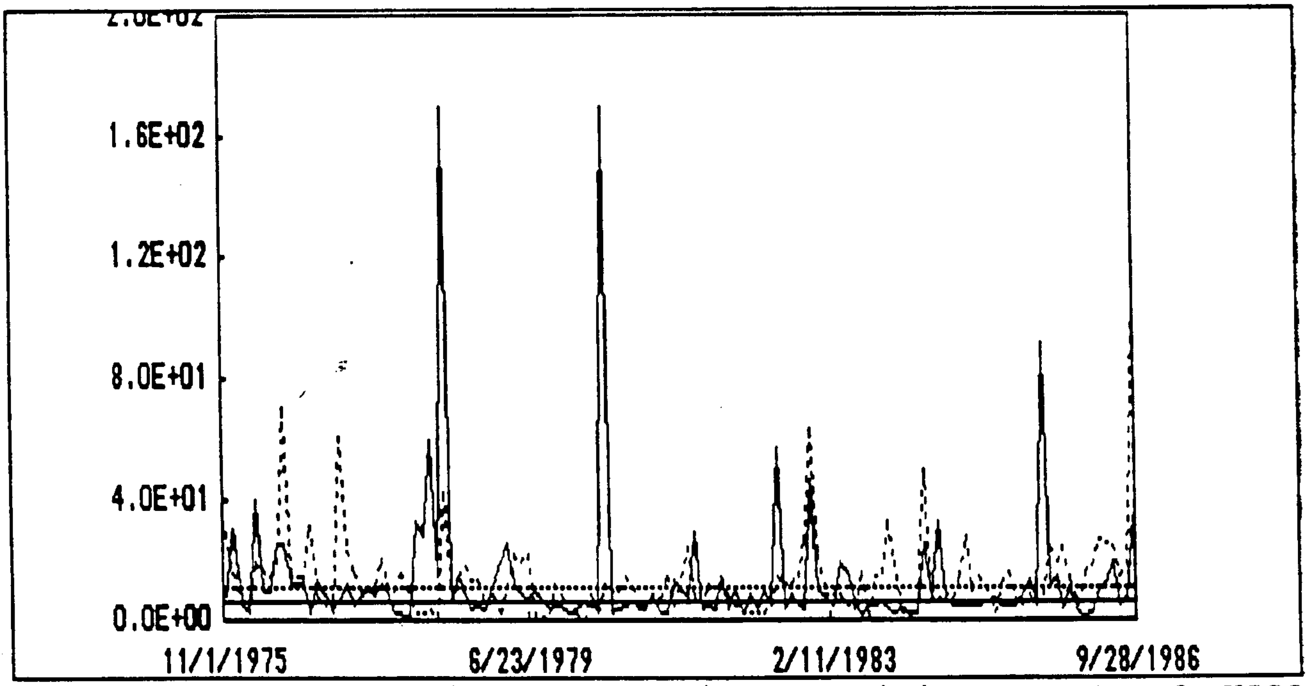


Figure I-16. Comparison of median turbidity (JTU) of USGS 07194800 (solid line) vs USGS 07195500 (dashed line) using the Wilcoxon signed rank test.

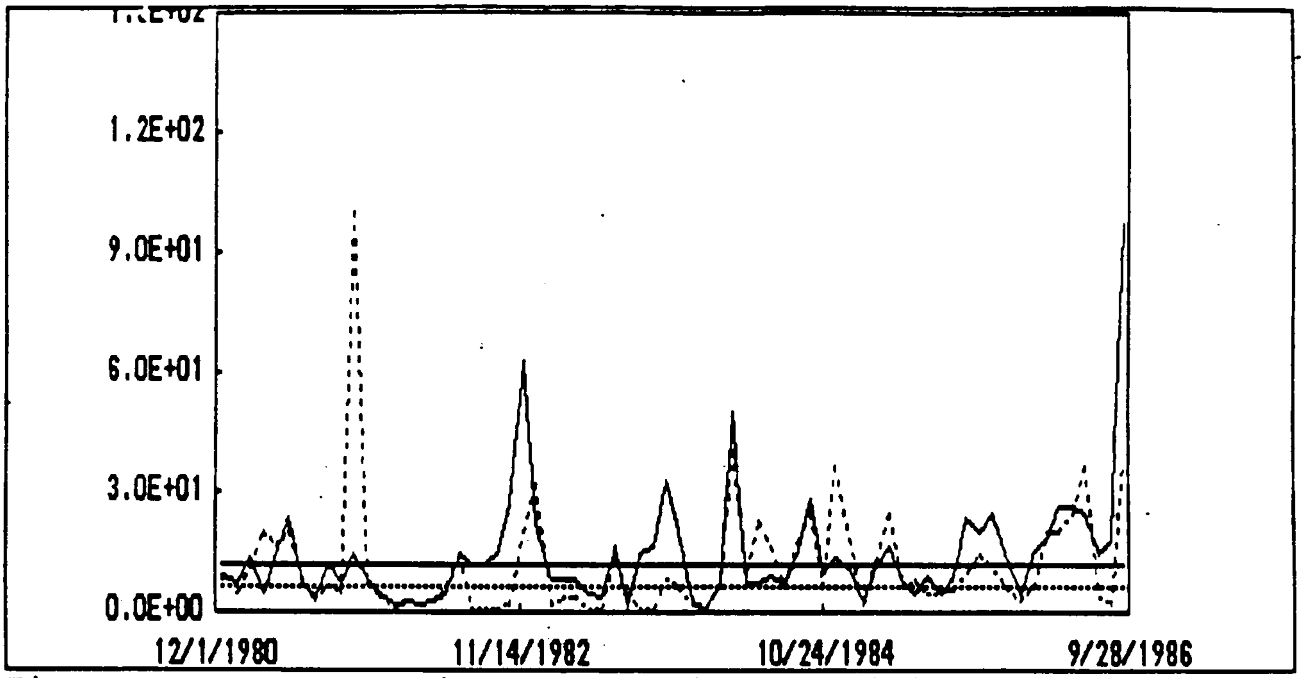


Figure I-17. Comparison of median turbidity (JTU) at USGS 07195500 (solid line) vs Okla. Scenic River SR-1 (dashed line) using the Wilcoxon signed rank test.

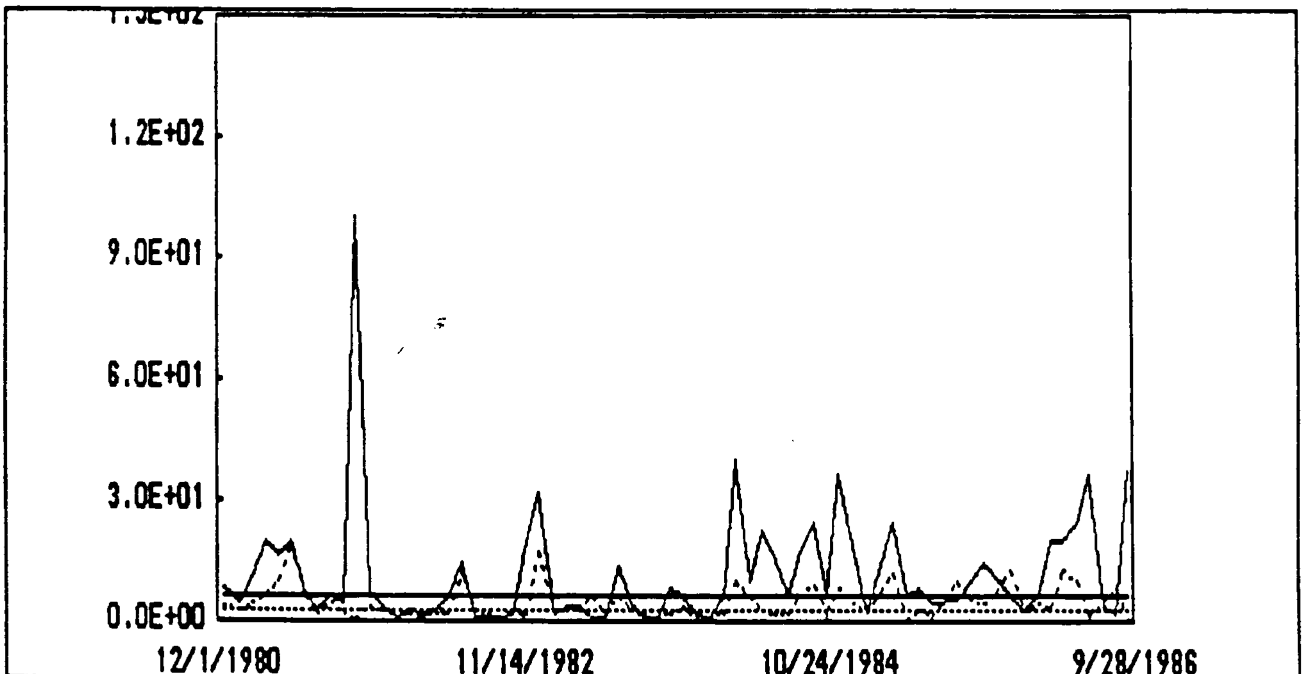
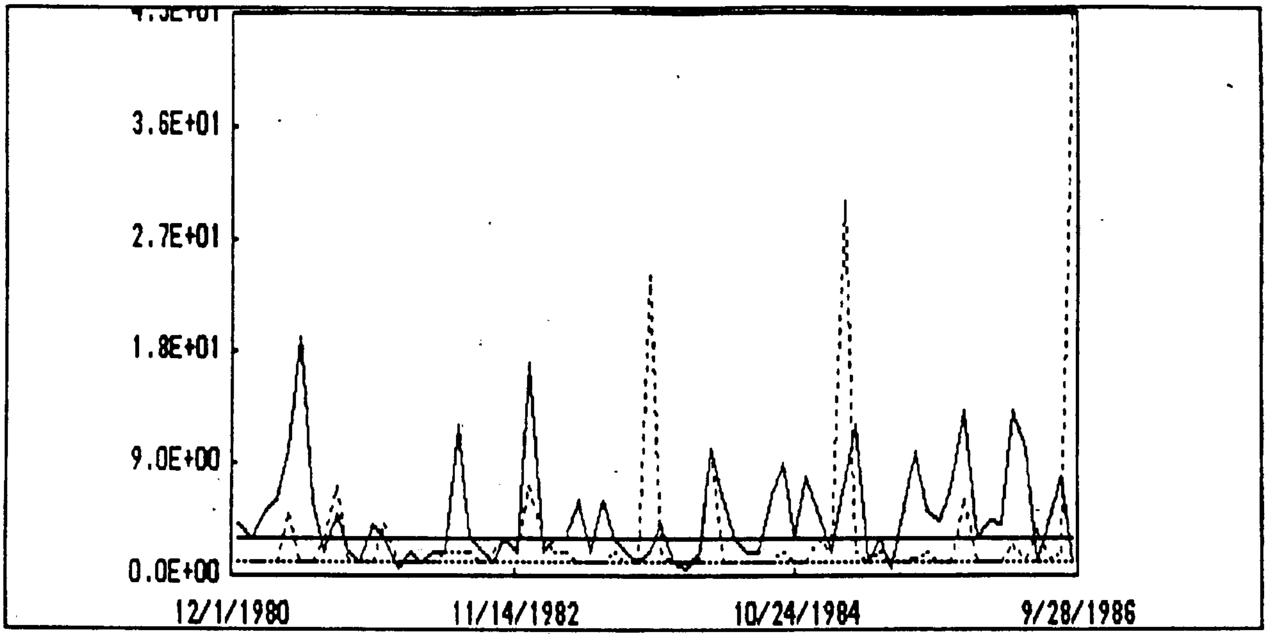


Figure I-18. Comparison of median turbidity (JTU) of Okla. Scenic River SR-1 (solid line) vs SR-2 (dashed line) using the Wilcoxon signed rank test.



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APPENDIX J

GRAPHIC ILLUSTRATION OF LONG TERM TEMPORAL TRENDS AND COMPARISON OF MEDIAN CONCENTRATIONS OF SUSPENDED SOLIDS IN UPSTREAM VS DOWNSTREAM STATIONS ALONG THE ILLINOIS RIVER

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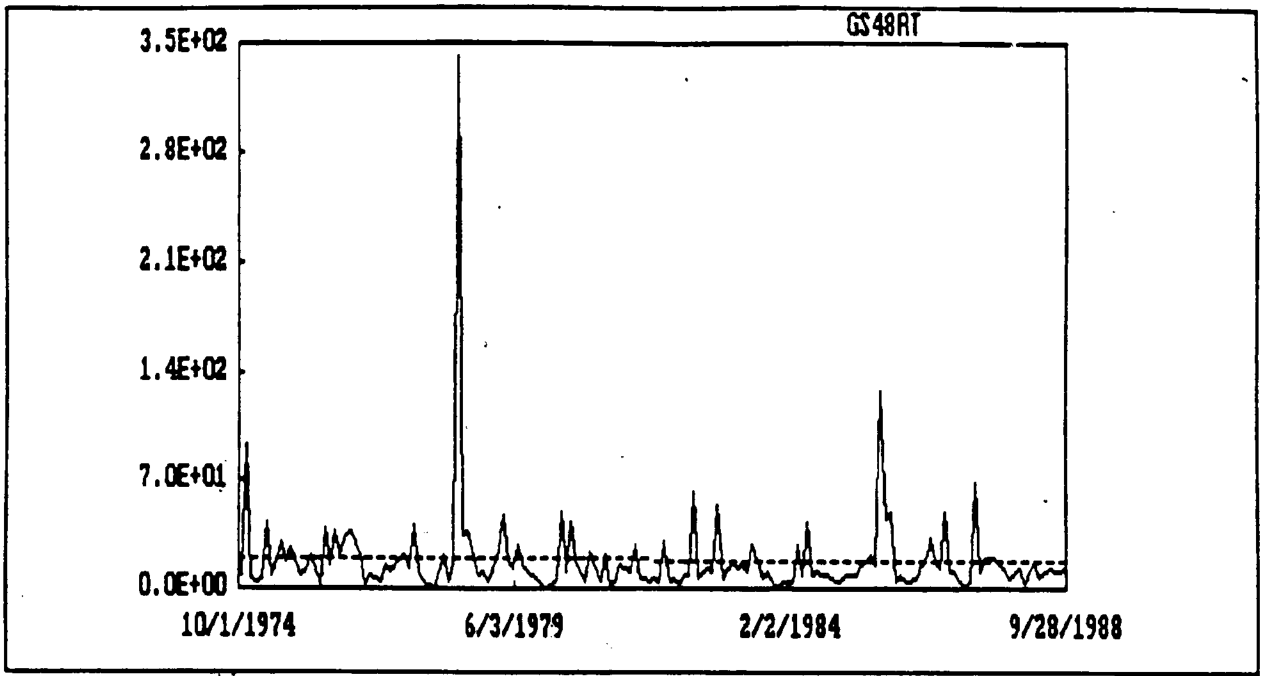
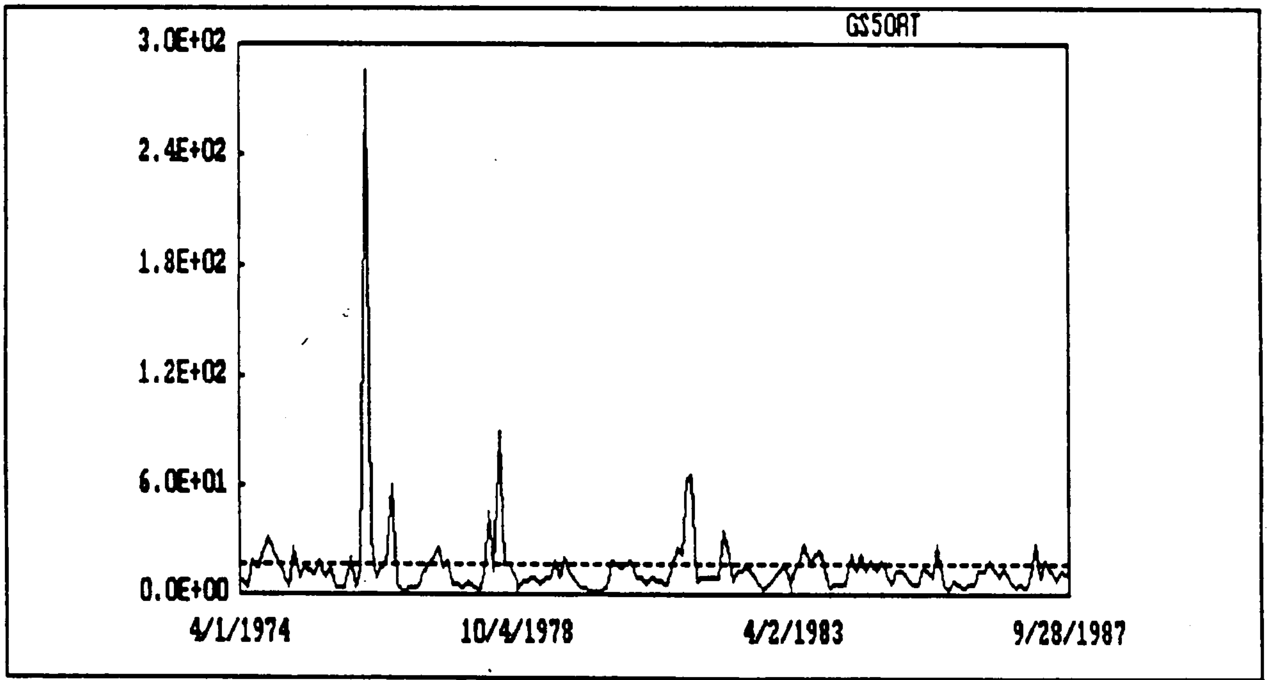


Figure J-1. Residue (total non-filterable) time series plot of monthly average concentration in mg/l at USGS 07194800. Seasonal Kendall Sen Slope Estimate = -0.118 mg/l/yr.



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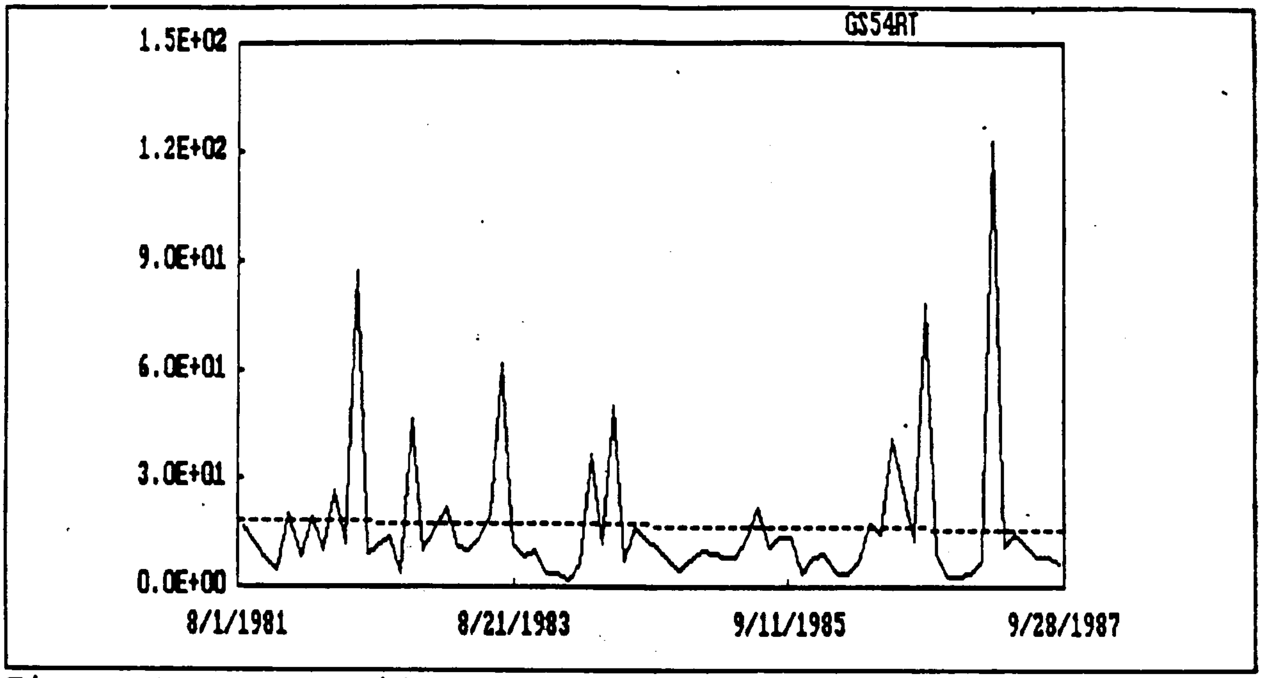

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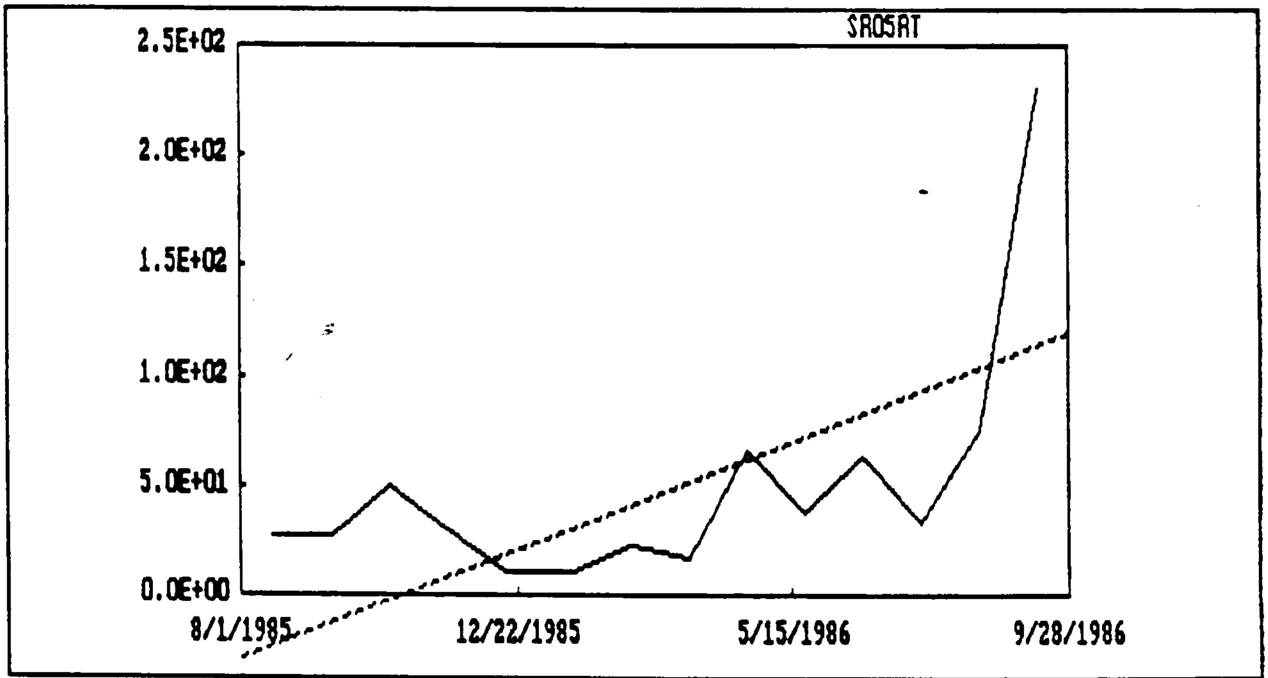

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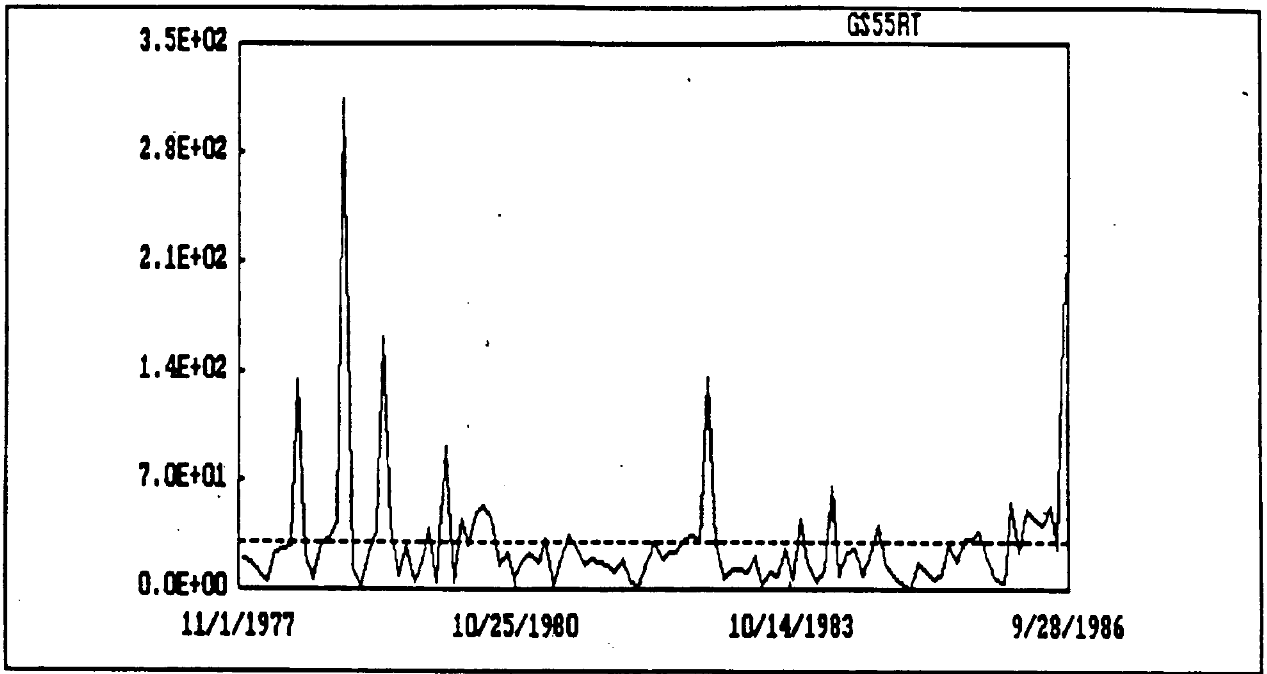

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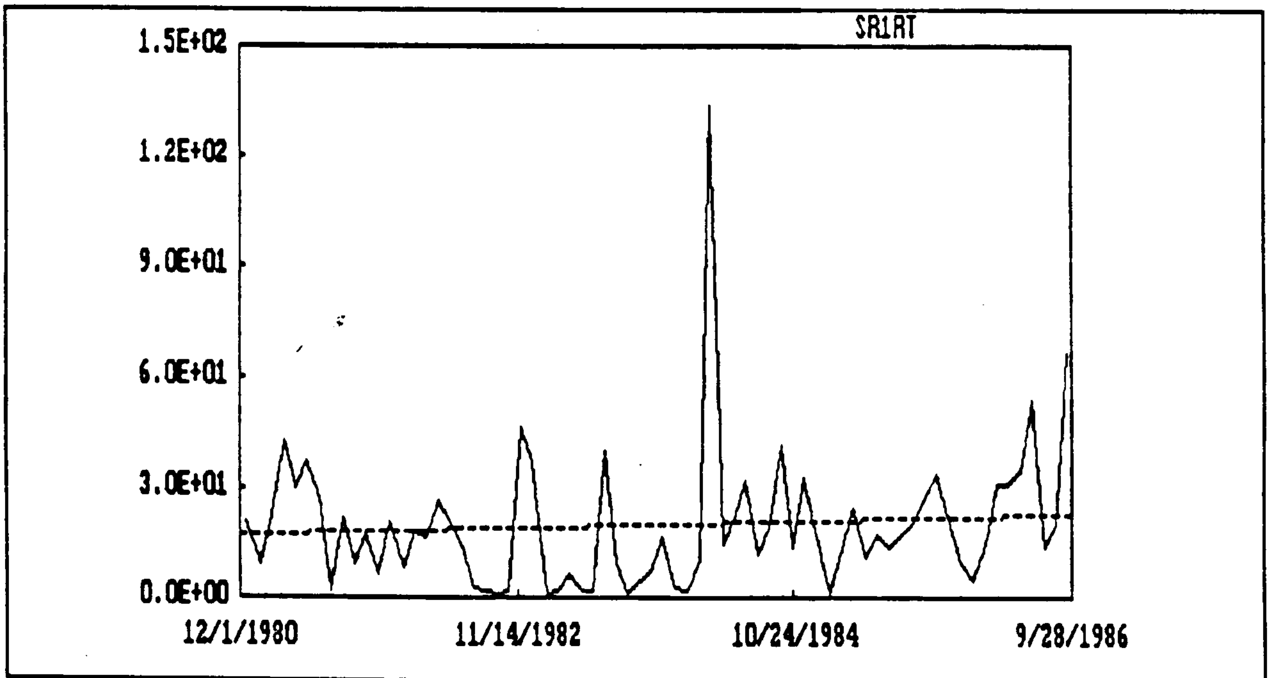
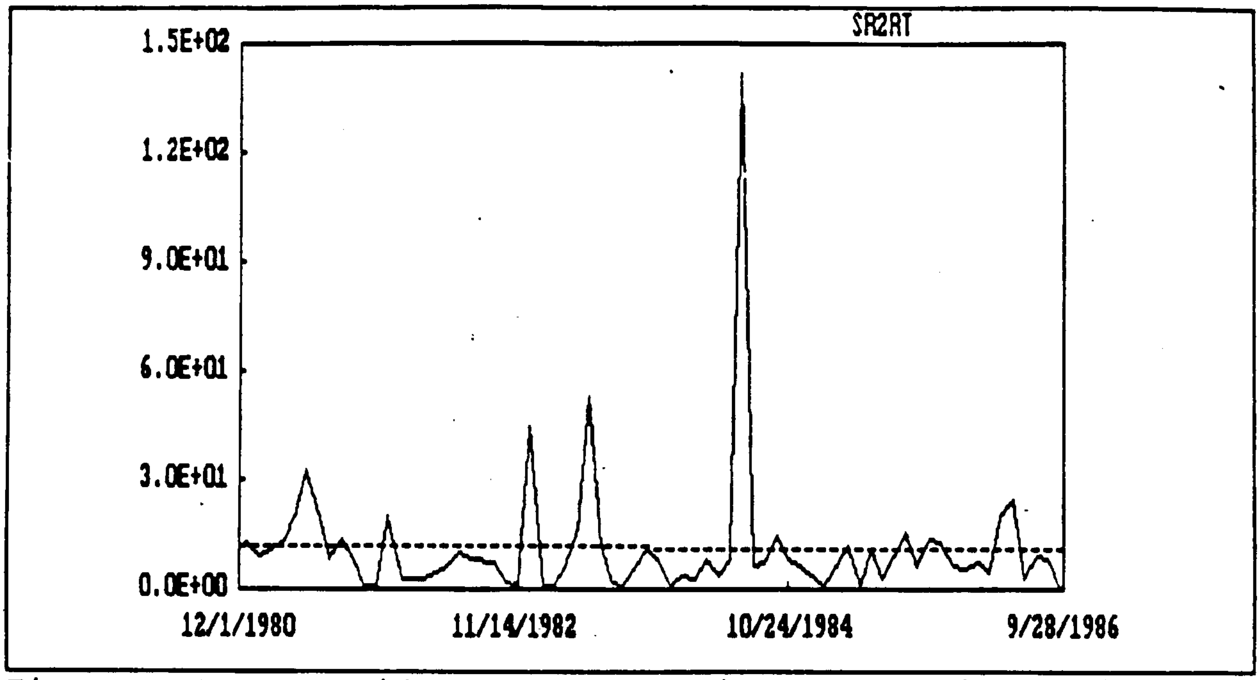


Figure J-6. Residue (total non-filterable) time series plot of monthly average concentration in mg/l at SR 1. Seasonal Kendall Sen Slope Estimate = 1.000 mg/l/yr.



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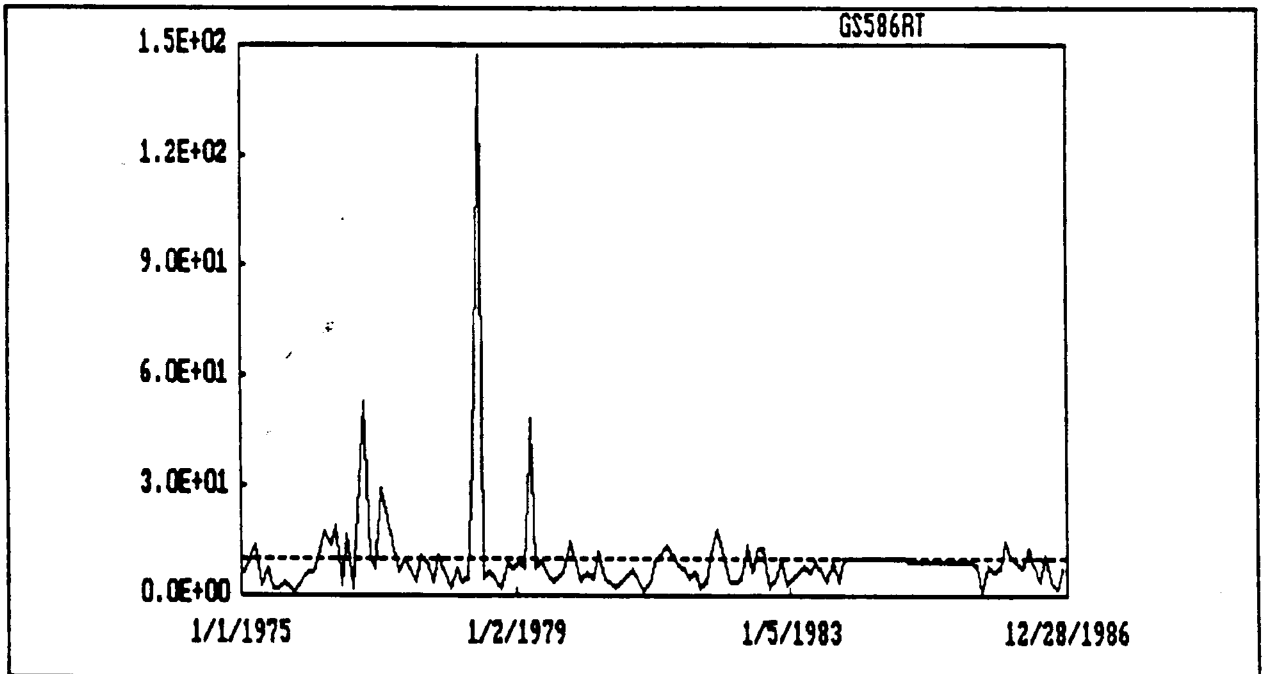

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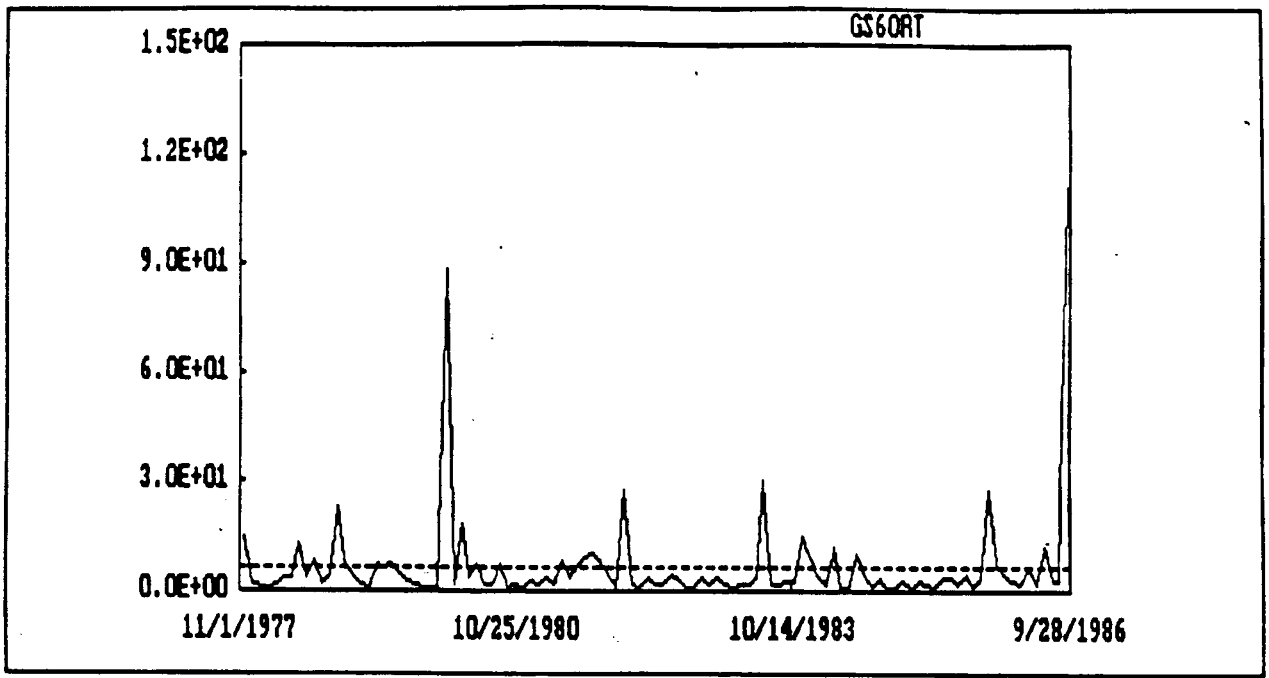

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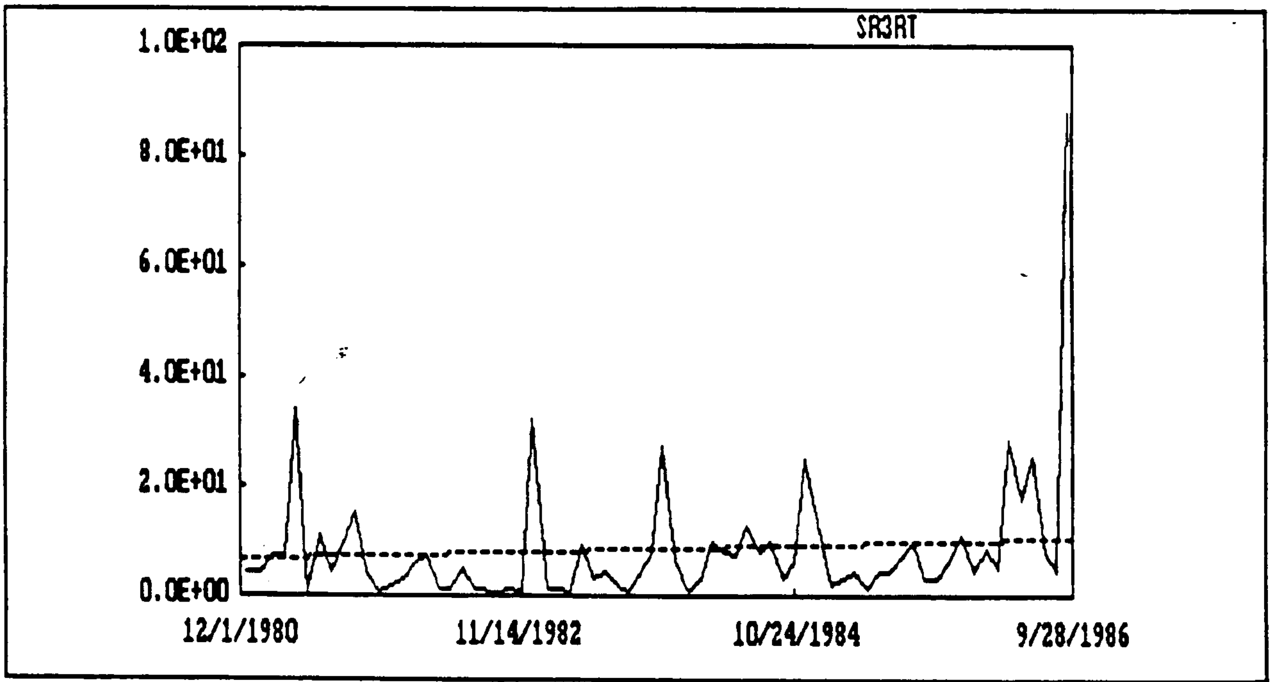

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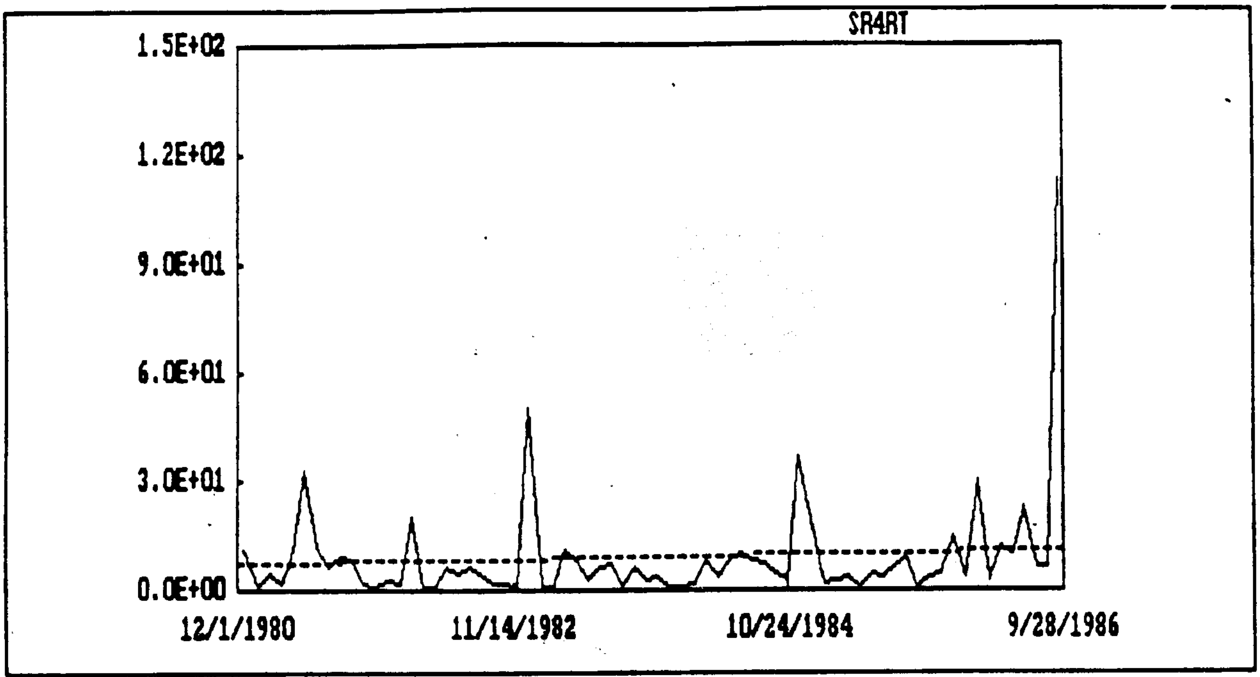

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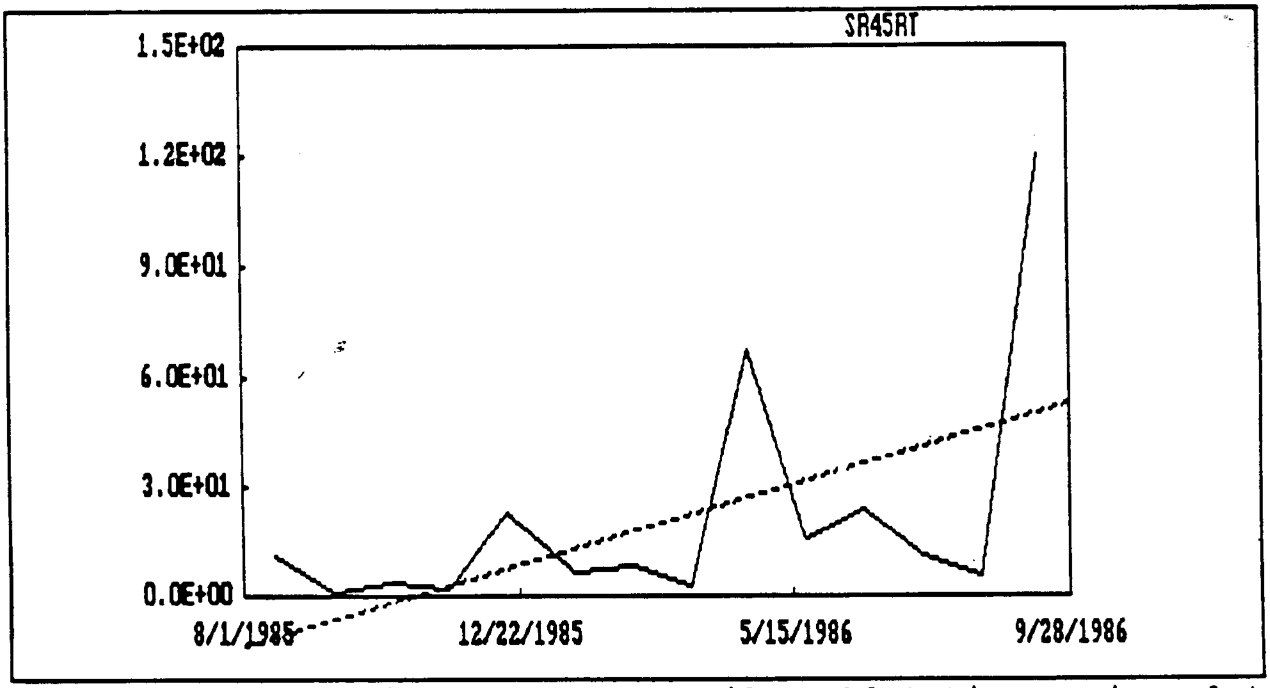

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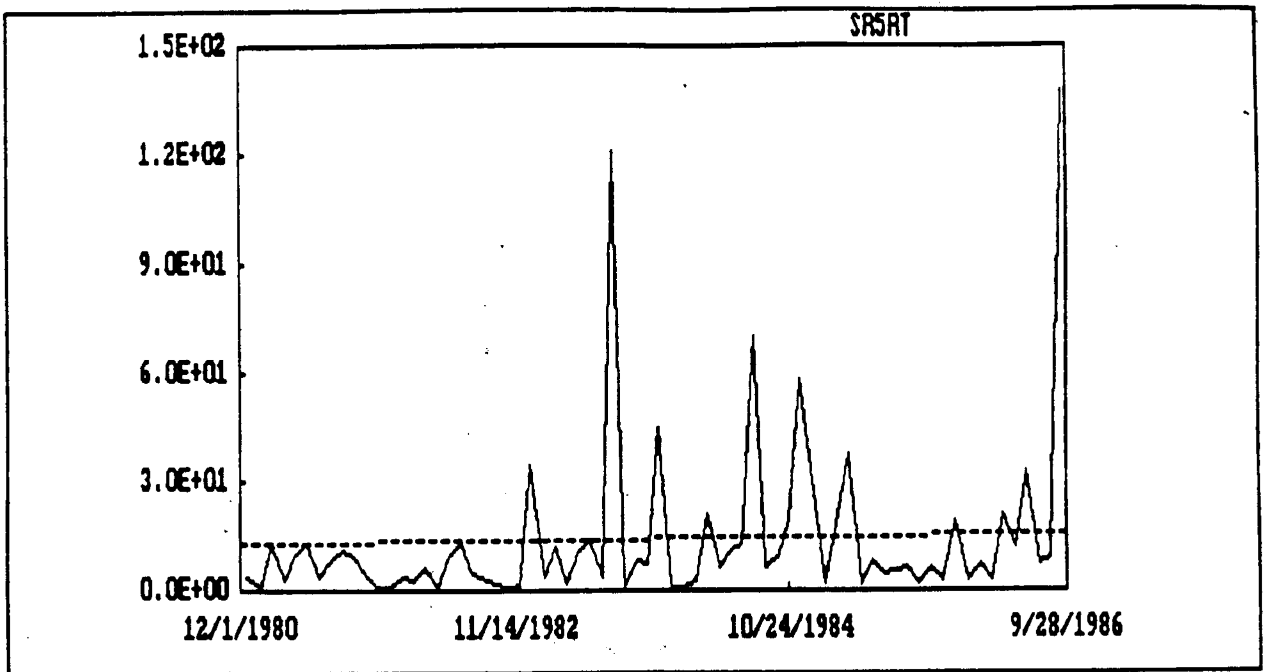

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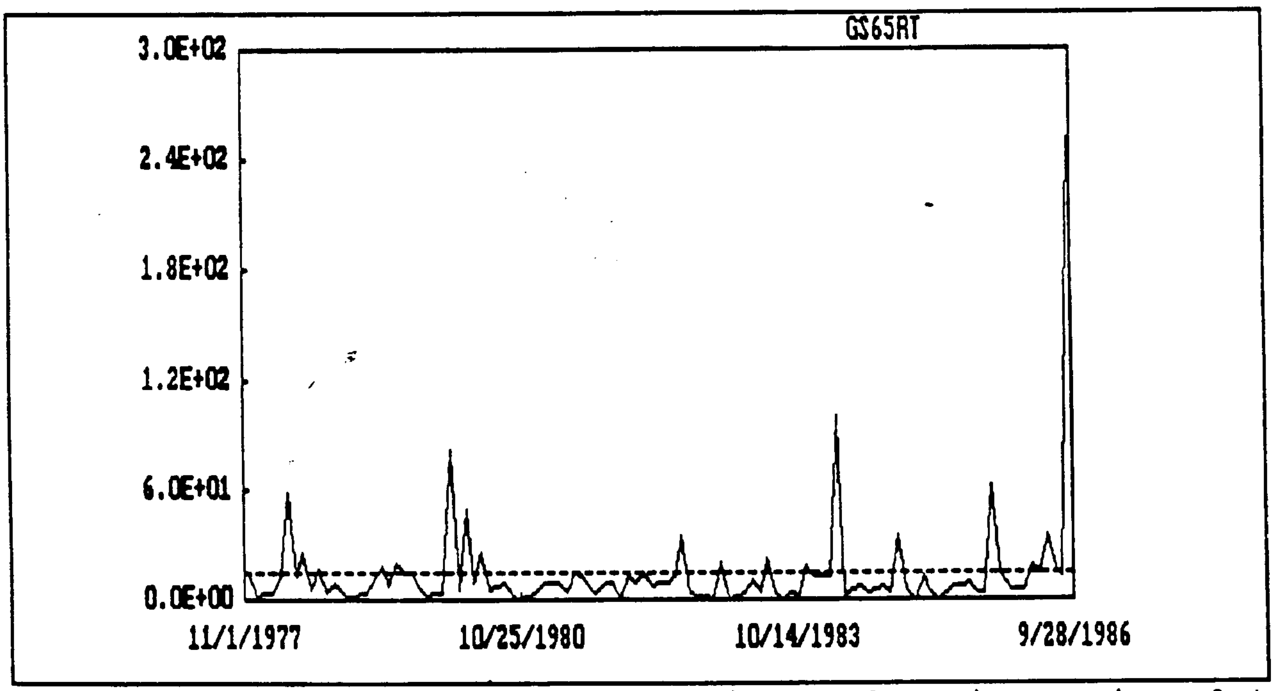

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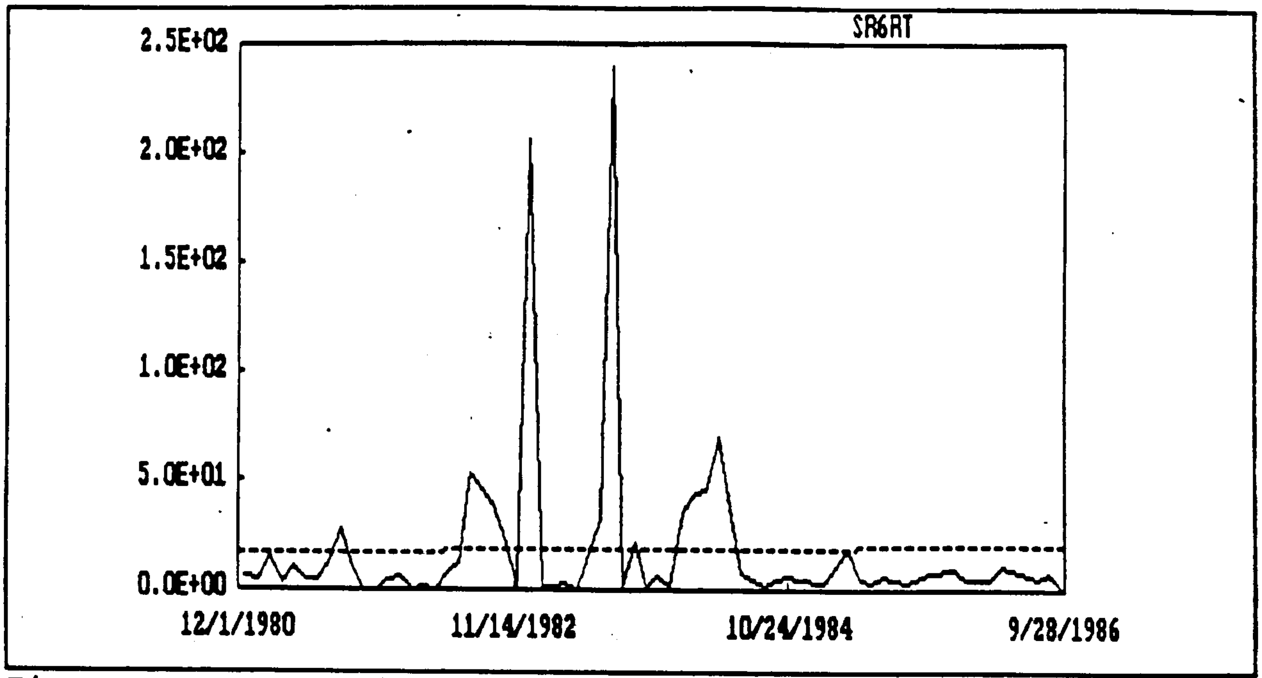

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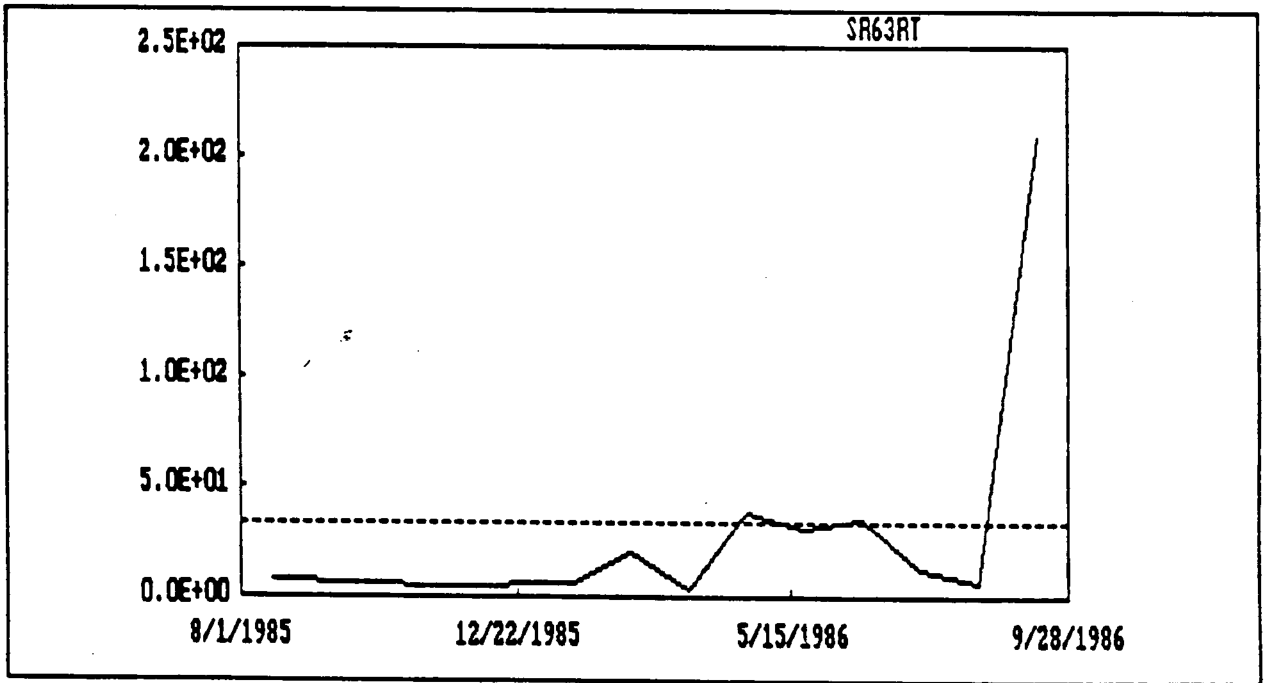

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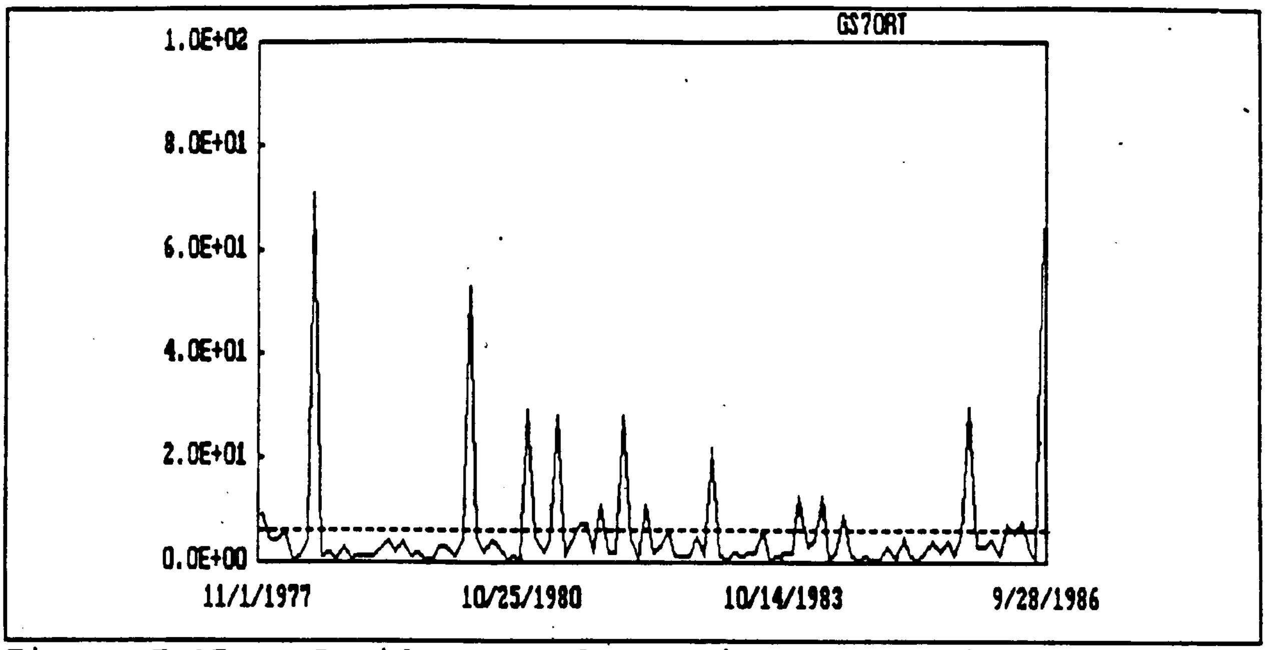


Figure J-17. Residue (total non-filterable) time series plot of monthly average concentration in mg/l at USGS 07197000. Seasonal Kendall Sen Slope Estimate = 0.000 mg/l/yr.

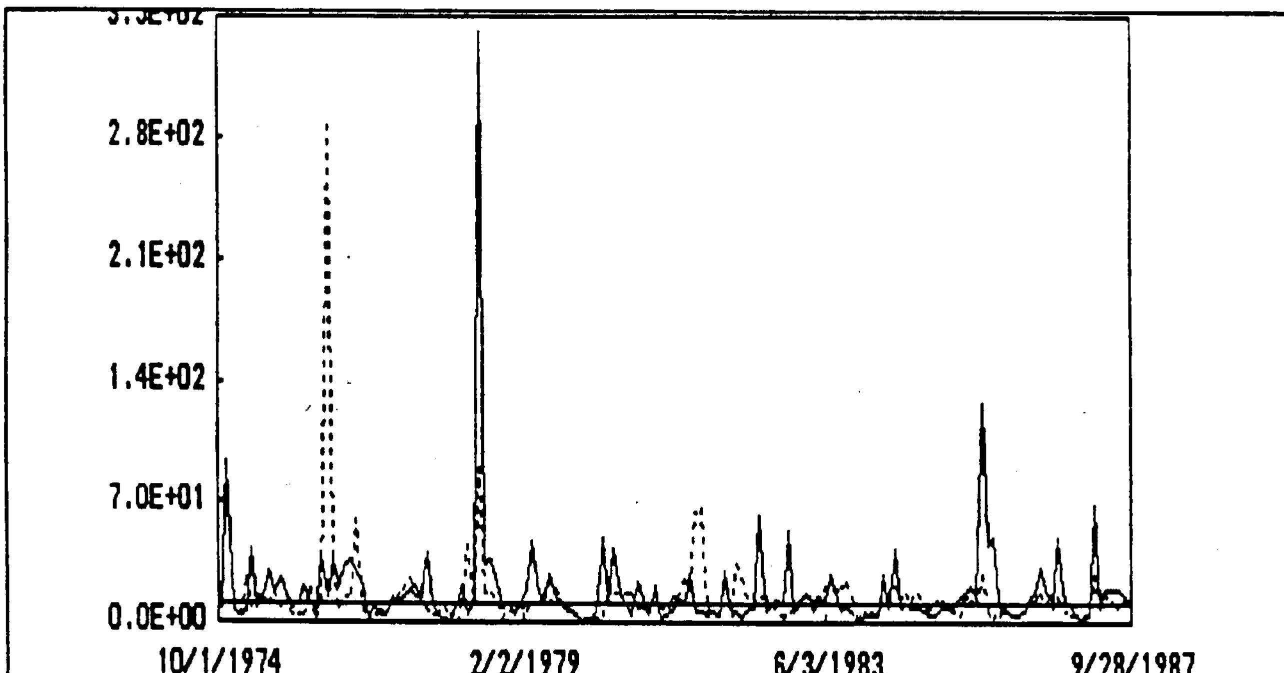


Figure J-18. Comparison of median suspended solids concentration (mg/l) of USGS 07194800 (solid line) vs USGS 07195000 (dashed line) using the Wilcoxon signed rank test.

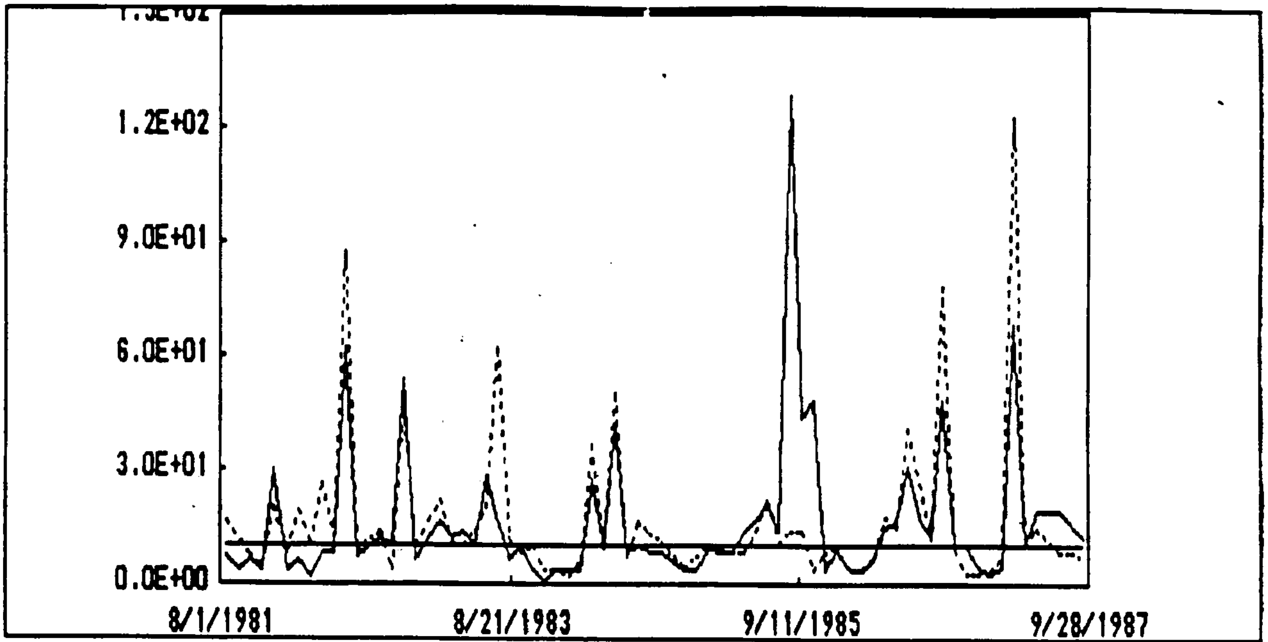


Figure J-19. Comparison of median suspended solids concentration (mg/l) of USGS 07194800 (solid line) vs USGS 07195400 (dashed line) using the Wilcoxon signed rank test.

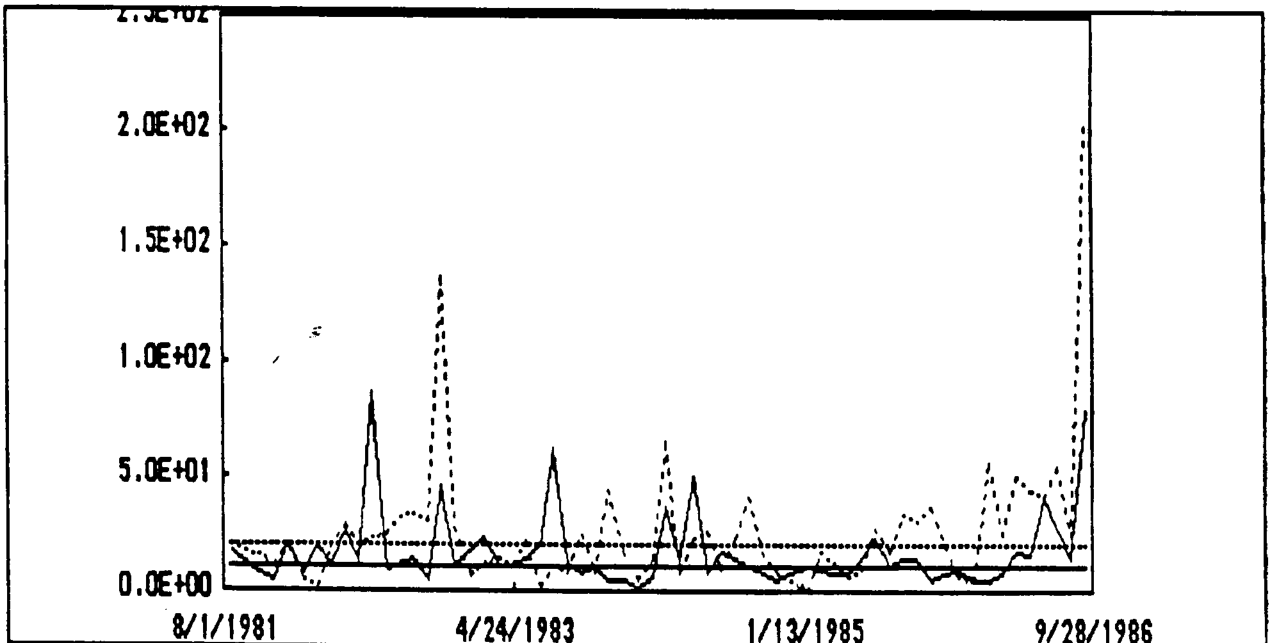
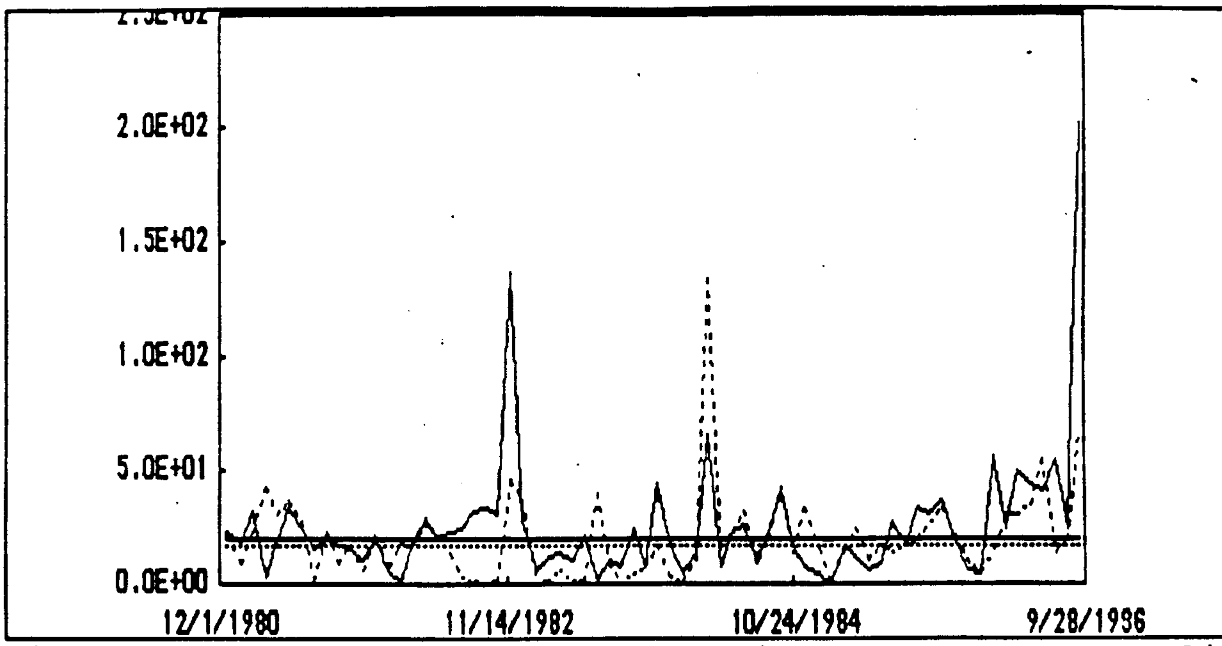


Figure J-20. Comparison of median suspended solids concentration (mg/l) of USGS 07195400 (solid line) vs USGS 07195500 (dashed line) using the Wilcoxon signed rank test.



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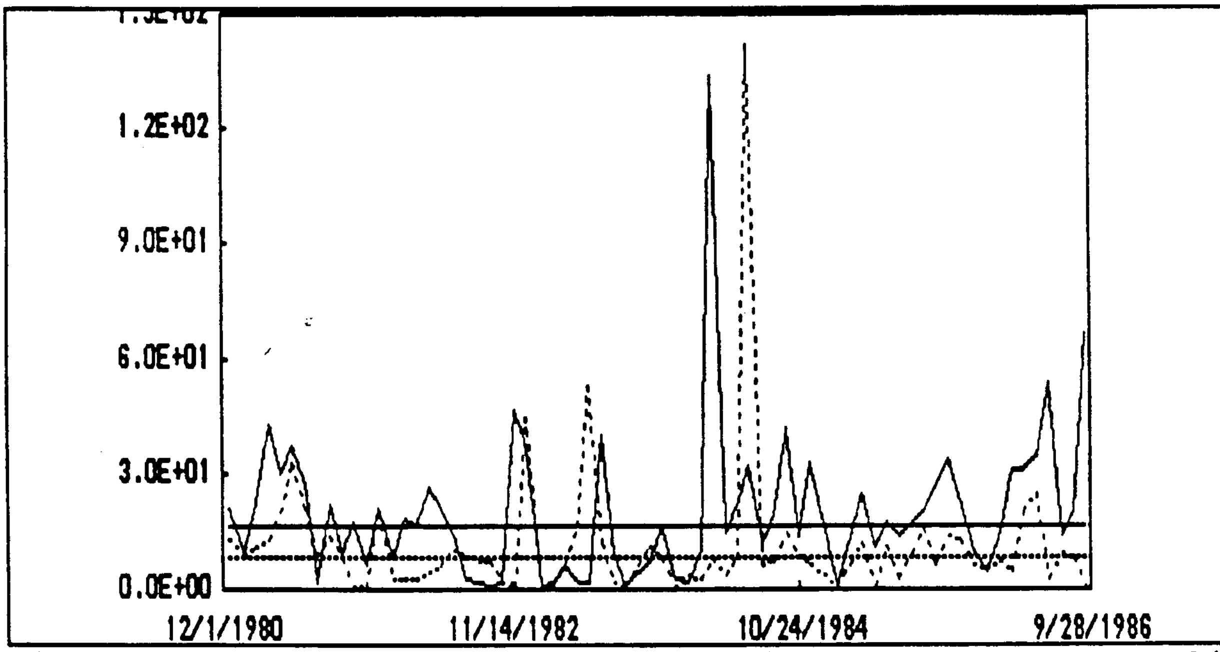

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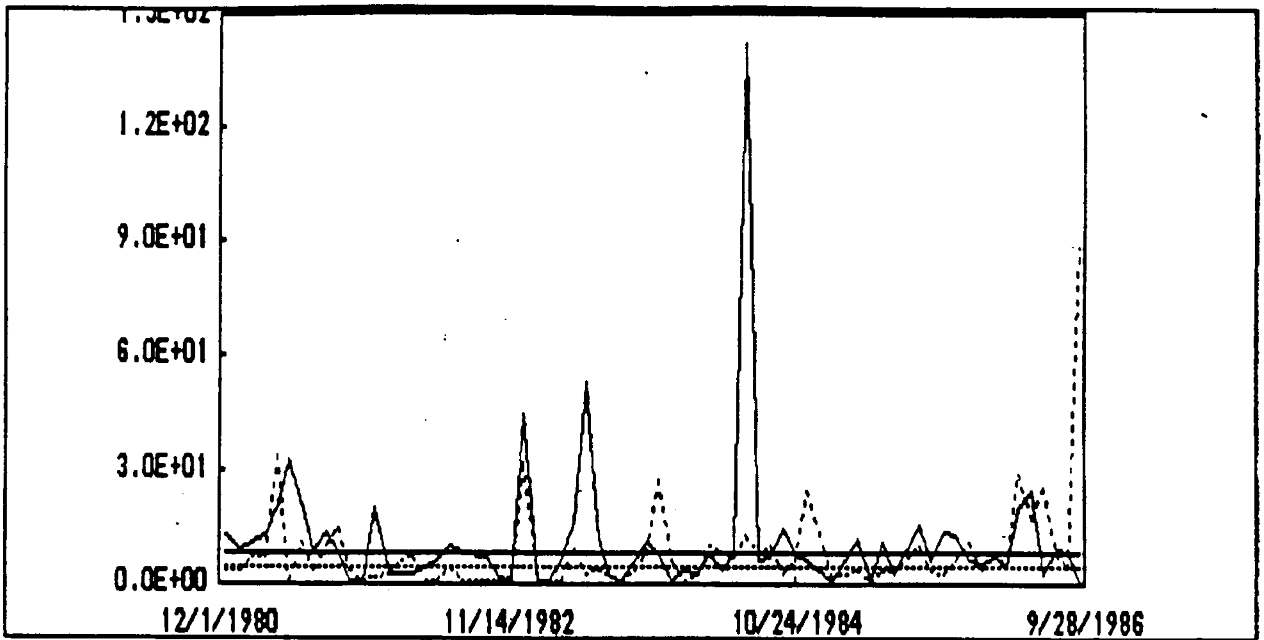

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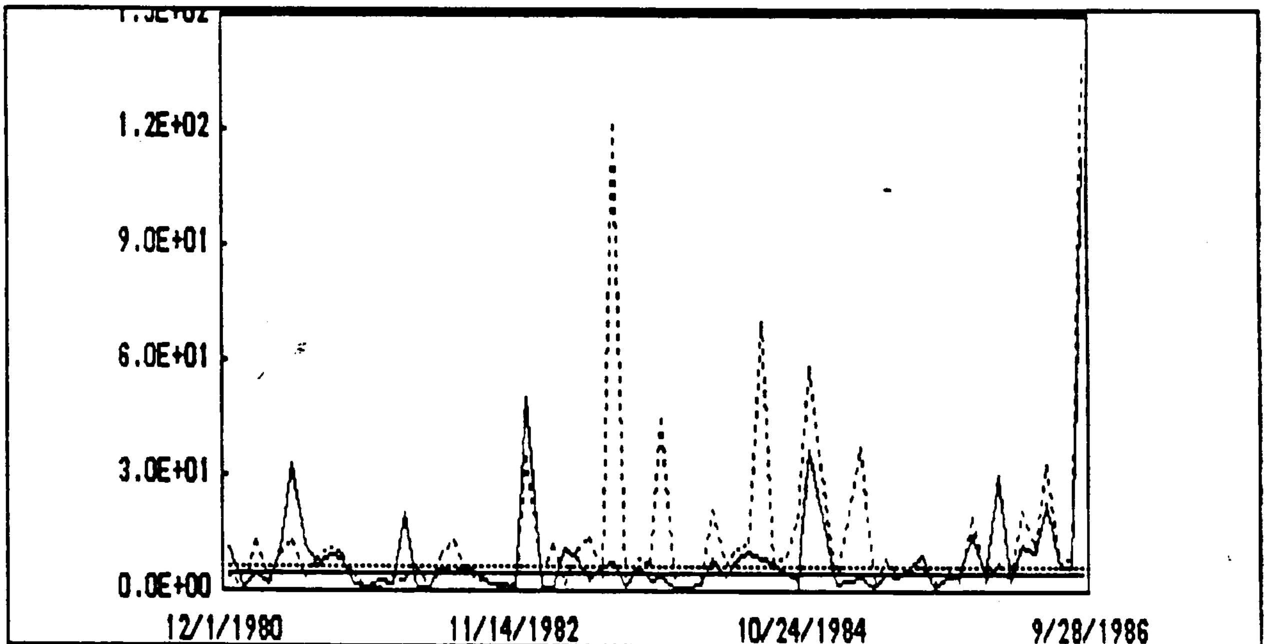

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APPENDIX K

GRAPHIC ILLUSTRATION OF LONG TERM

TEMPORAL TRENDS OF

TOTAL PHOSPHORUS, NITRITE + NITRATE,

AND RESIDUE (T-NFLT)

ANNUAL LOADINGS IN ILLINOIS RIVER

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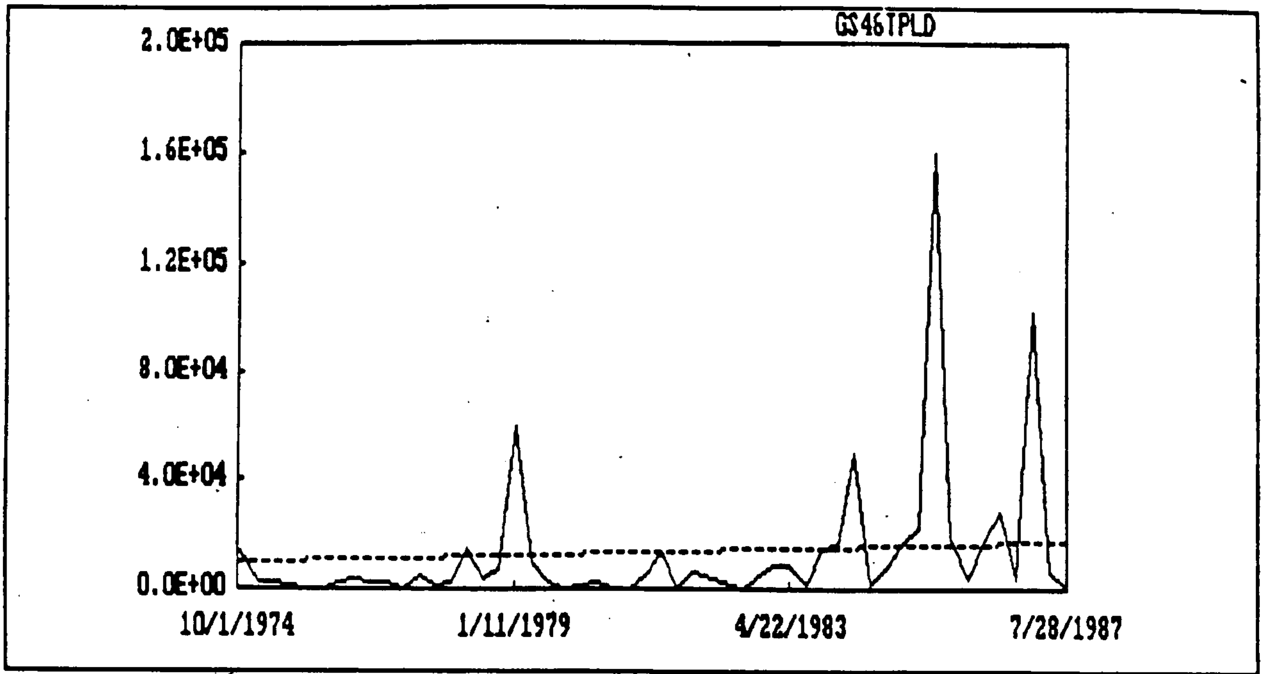
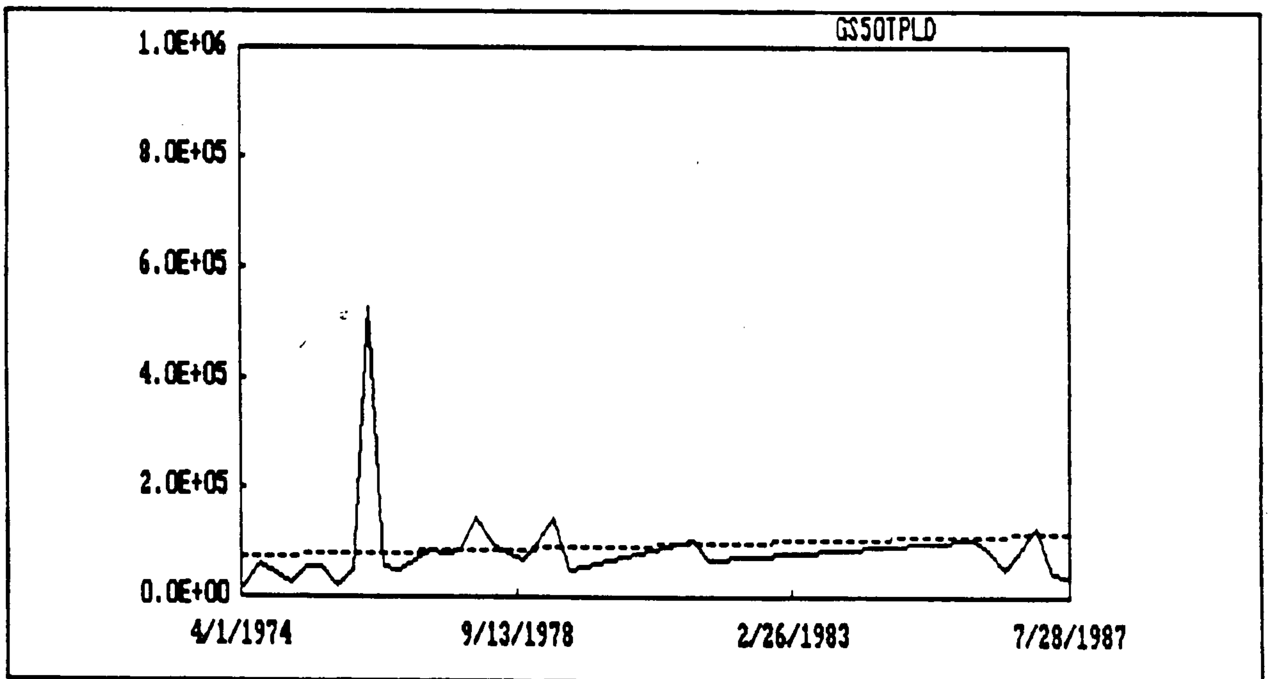


Figure K-1. Total phosphorus (as P) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07194800. Seasonal Kendall Sen Slope Estimate = 611 kg/yr/yr.



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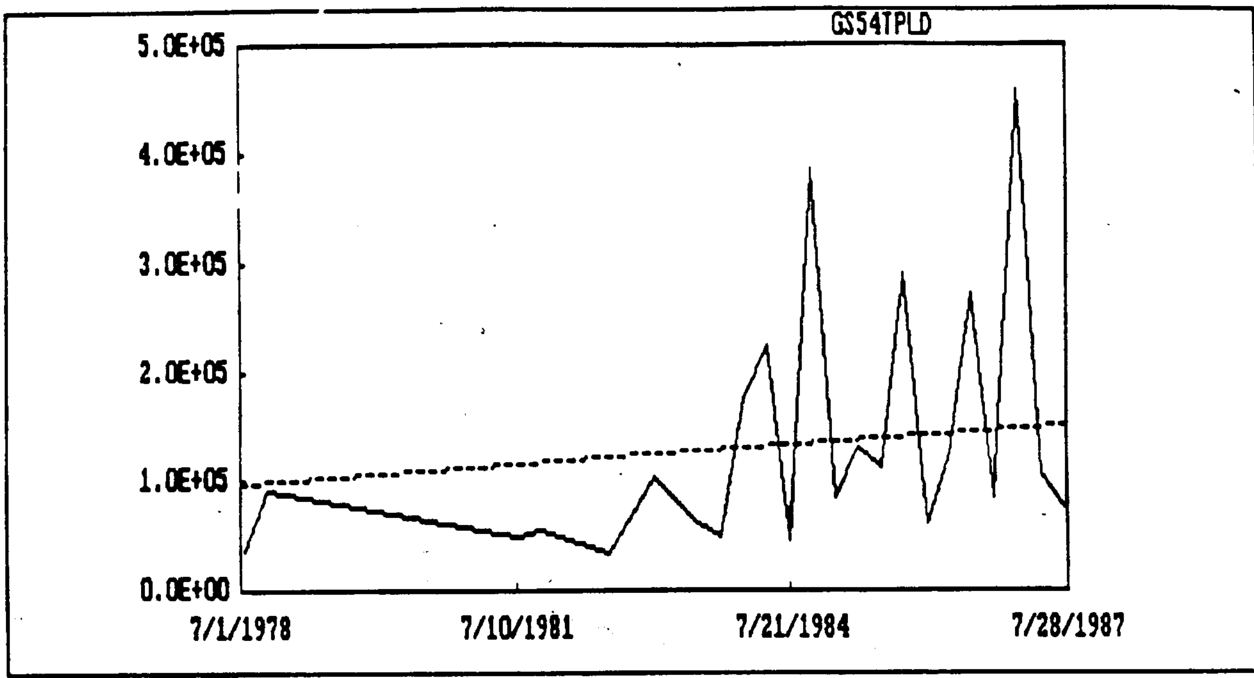


Figure K-3. Total phosphorus (as P) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07195400. Seasonal Kendall Sen Slope Estimate = 6,162 kg/yr/yr.

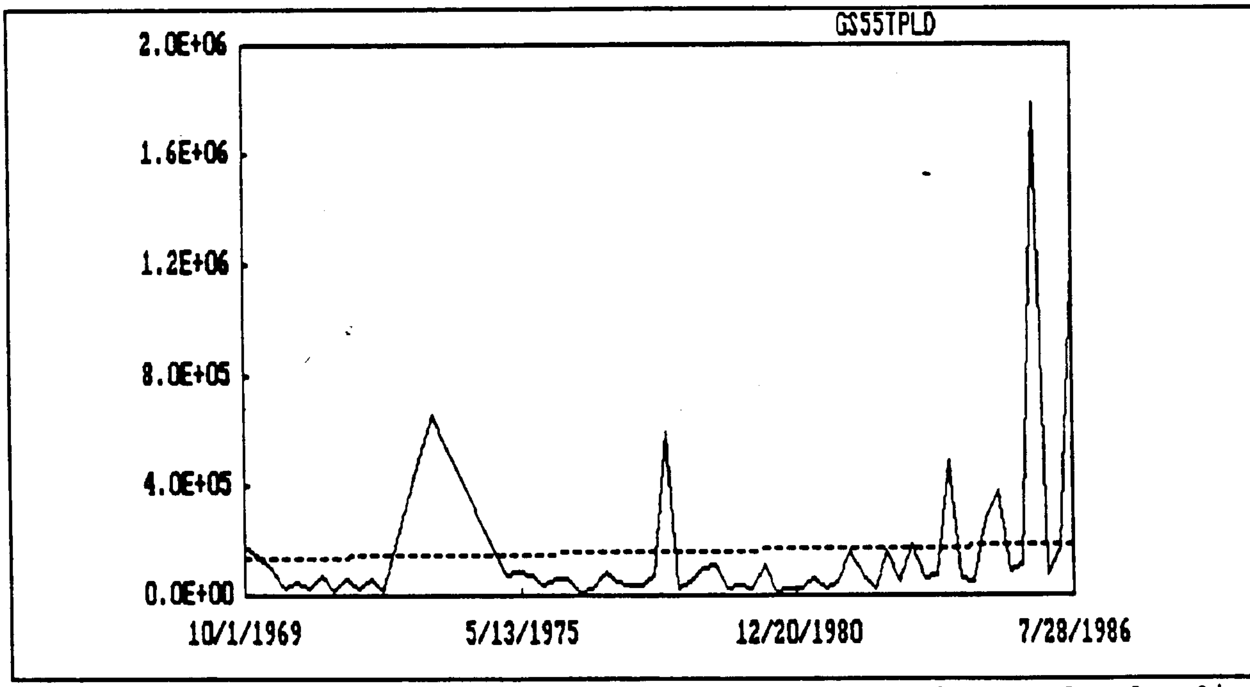
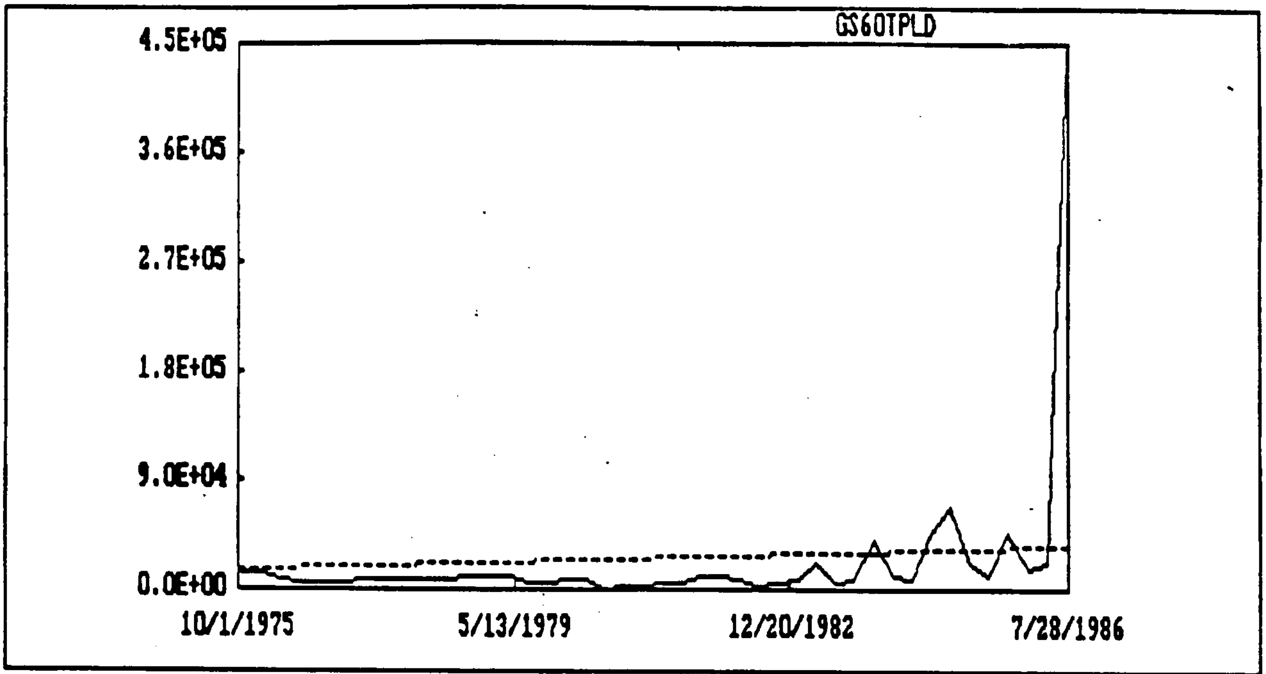


Figure K-4. Total phosphorus (as P) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07195500. Seasonal Kendall Sen Slope Estimate = 2,575 kg/yr/yr.



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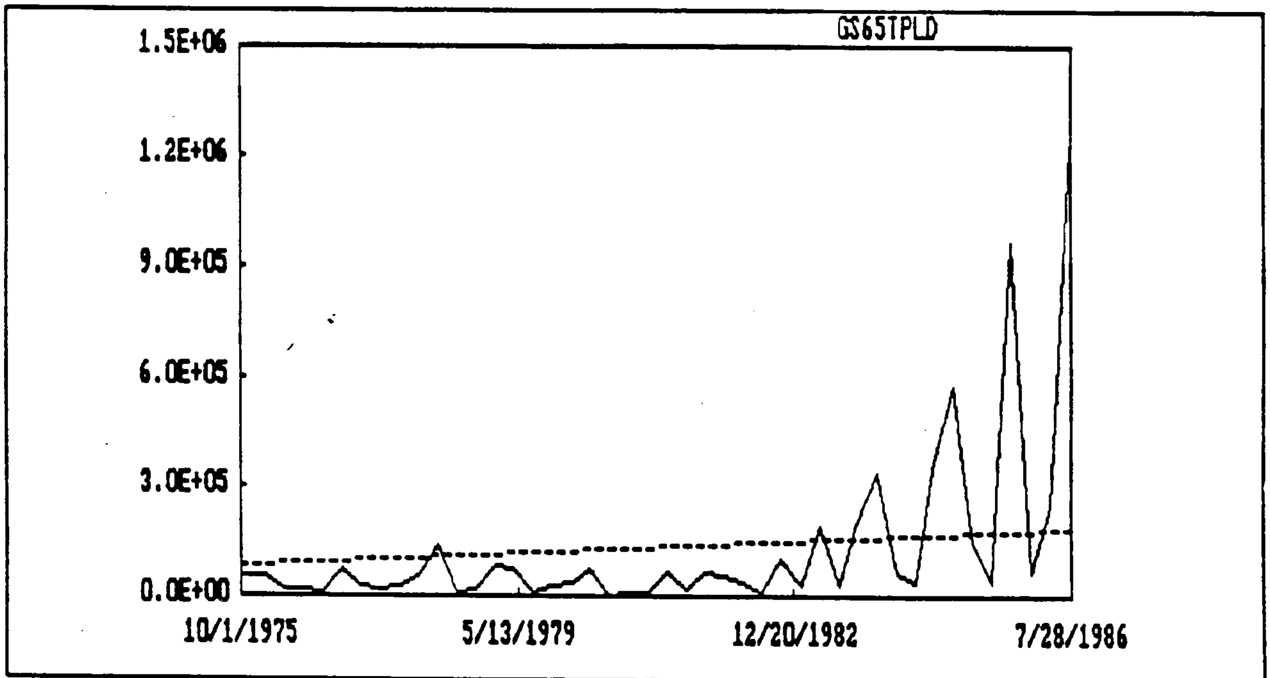


Figure K-6. Total phosphorus (as P) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07196500. Seasonal Kendall Sen Slope Estimate = 9,102 kg/yr/yr.

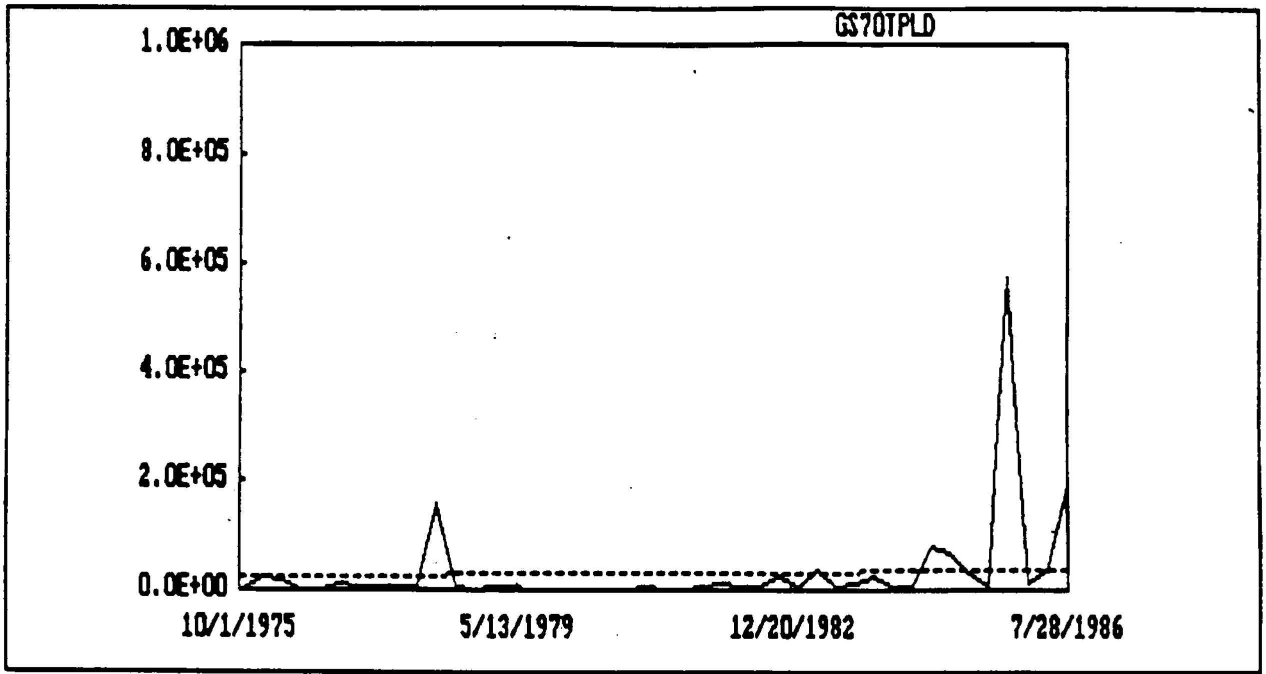
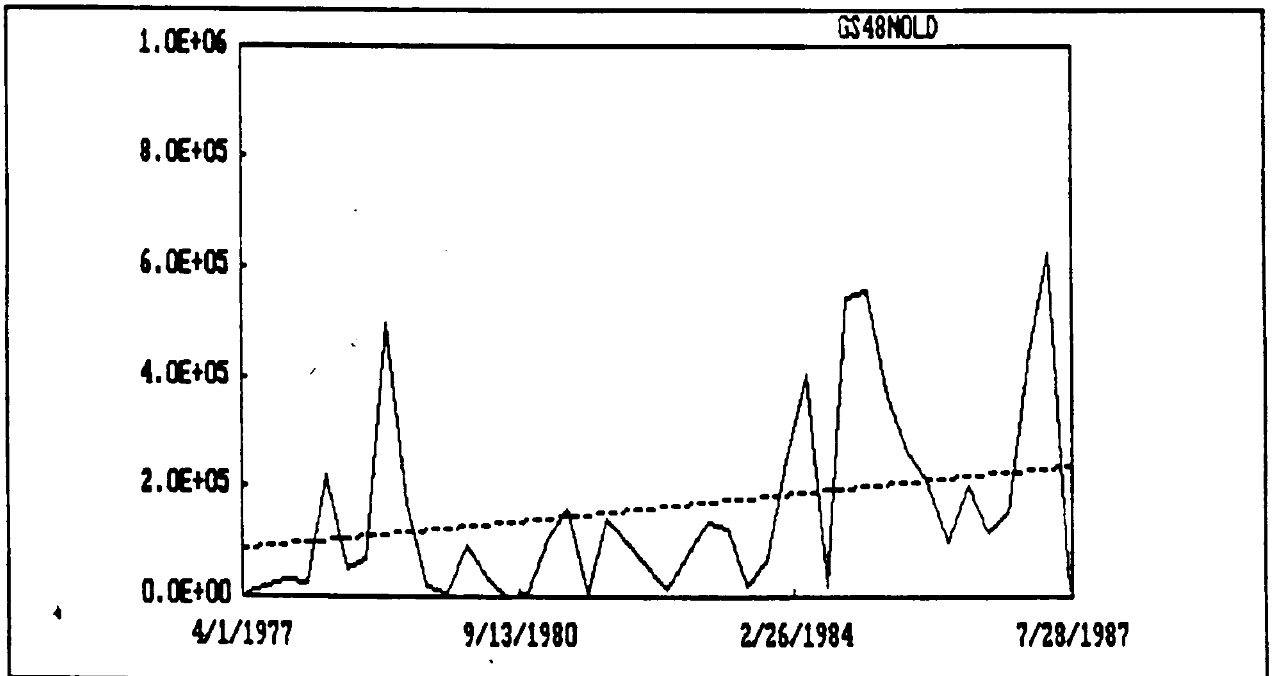


Figure K-7. Total phosphorus (as P) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07197000. Seasonal Kendall Sen Slope Estimate = 1,013 kg/yr/yr.



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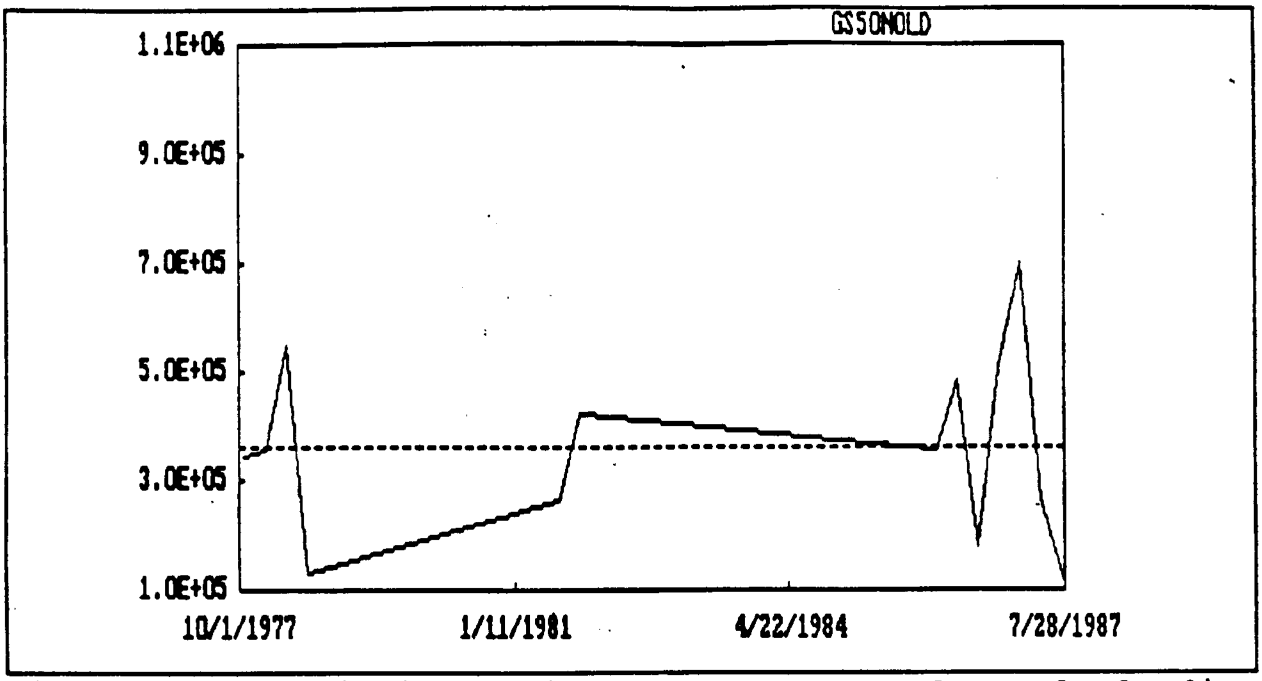

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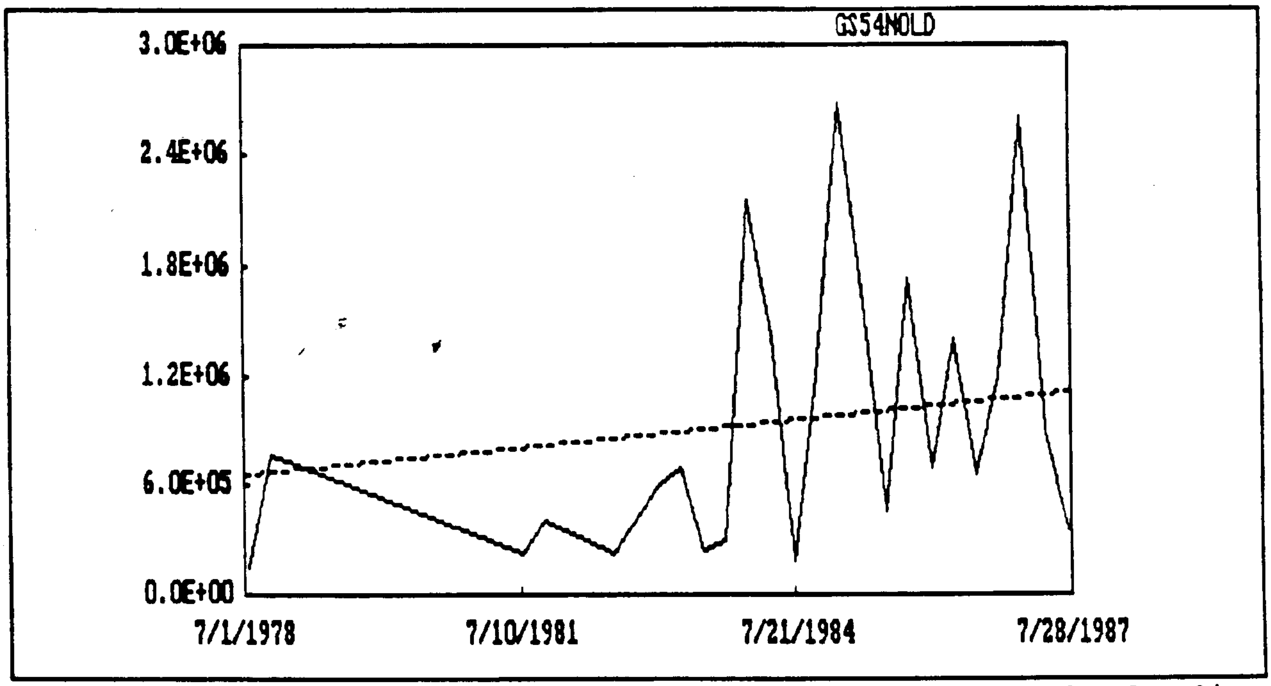

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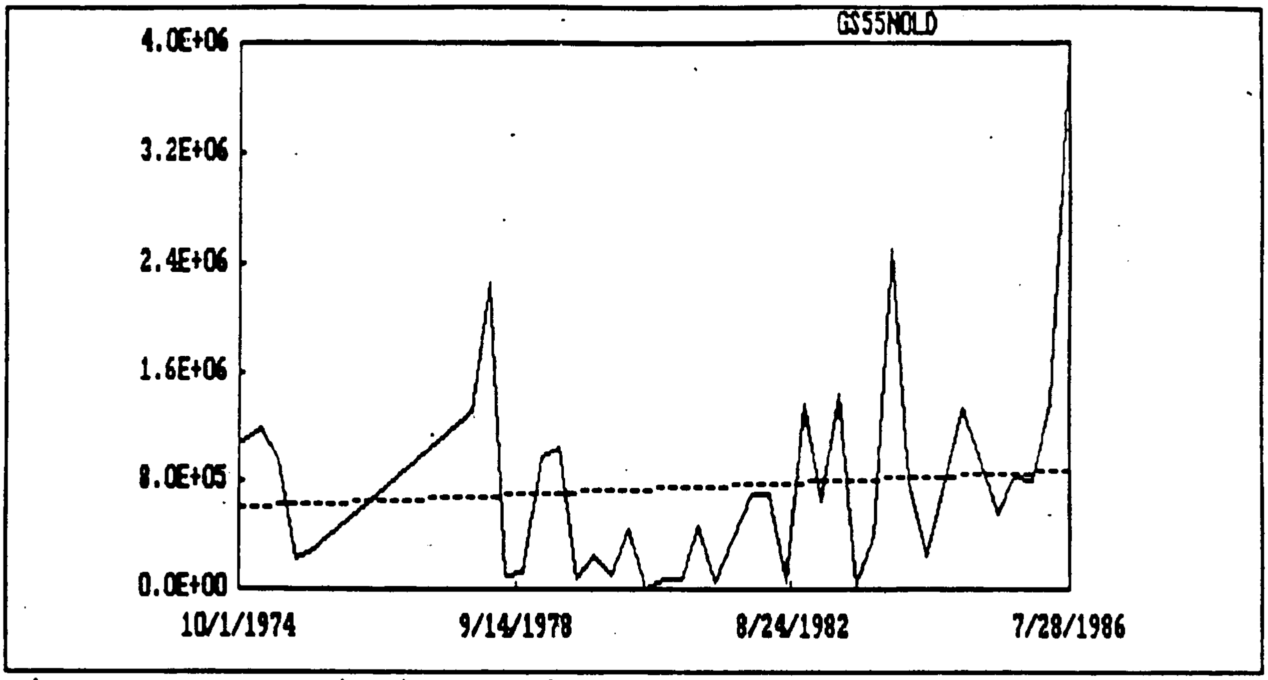


Figure K-11: Nitrite + nitrate (as N) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07195500. Seasonal Kendall Sen Slope Estimate = 22,477 kg/yr/yr.

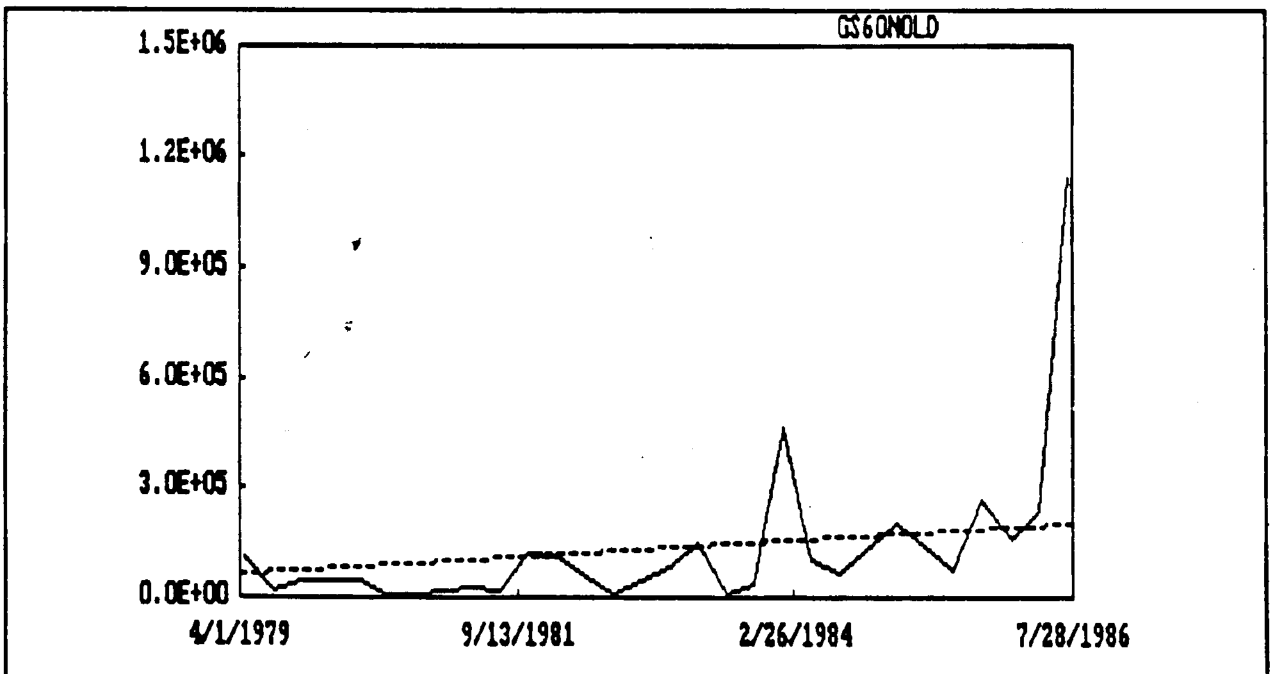


Figure K-12. Nitrite + nitrate (as N) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07196000. Seasonal Kendall Sen Slope Estimate = 18,473 kg/yr/yr.

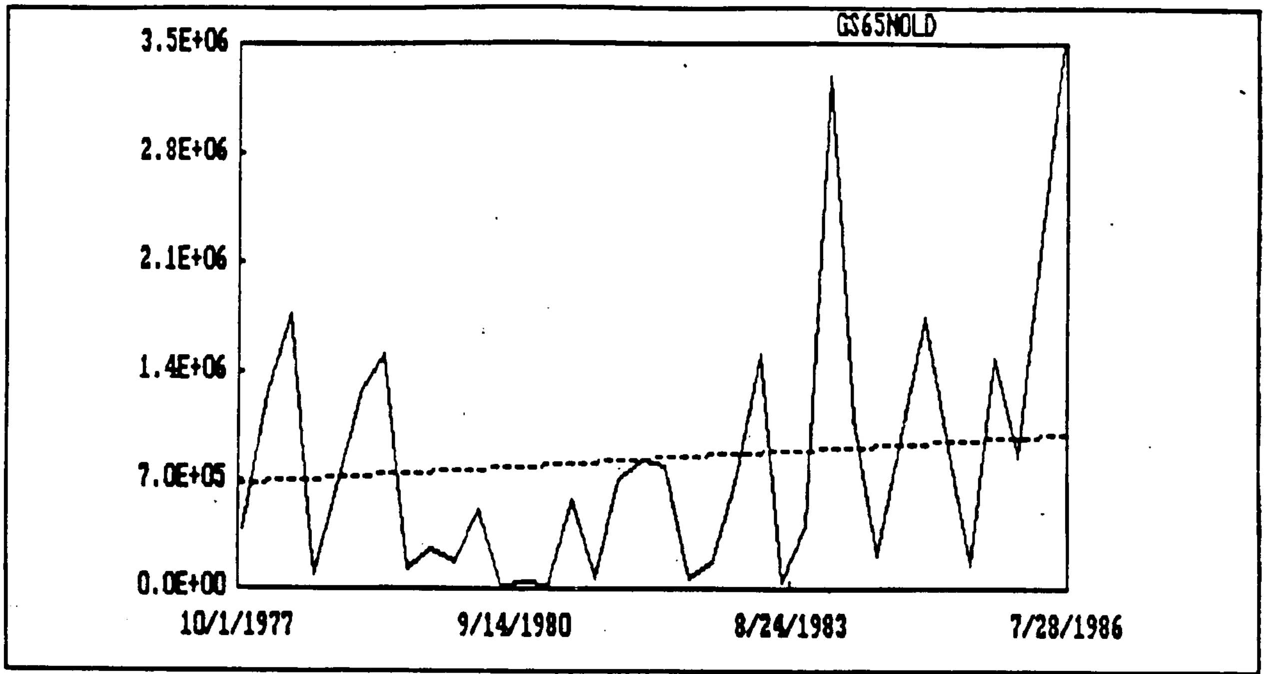


Figure K-13. Nitrite + nitrate (as N) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07196500. Seasonal Kendall Sen Slope Estimate = 36,058 kg/yr/yr.

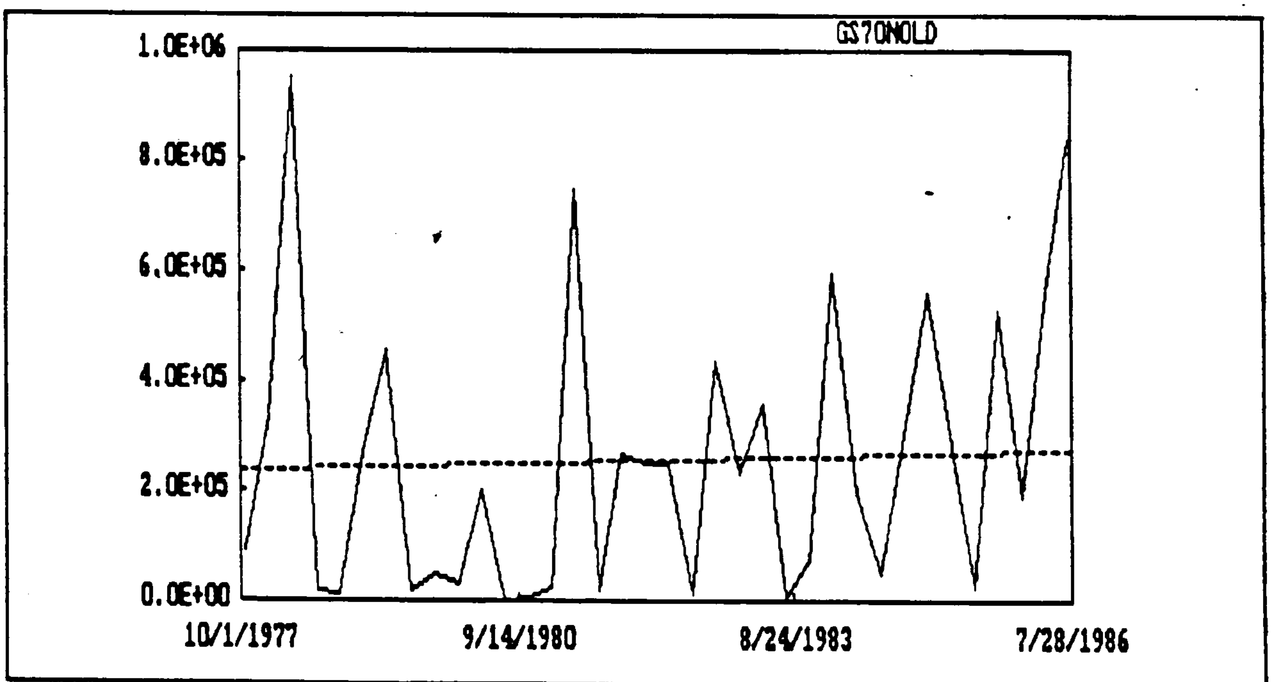


Figure K-14. Nitrite + nitrate (as N) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07197000. Seasonal Kendall Sen Slope Estimate = 4,605 kg/yr/yr.

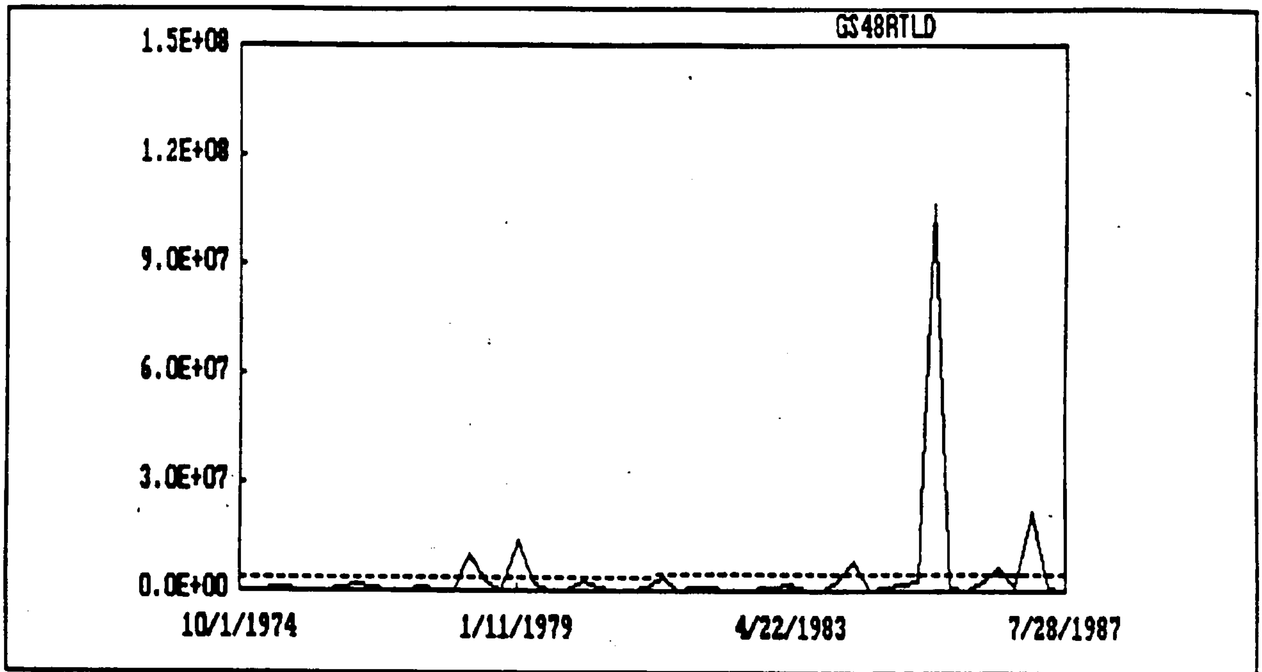
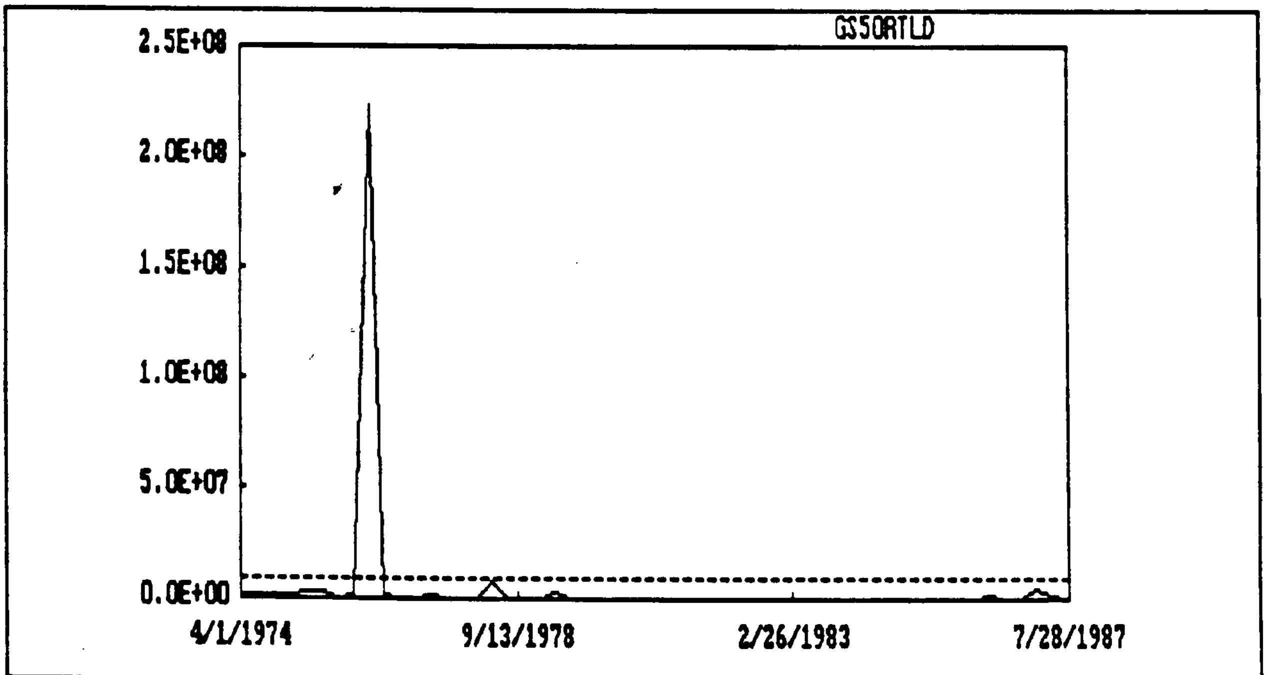


Figure K-15. Residue (T-NFLT) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07194800. Seasonal Kendall Sen Slope Estimate = 49,658 kg/yr/yr.



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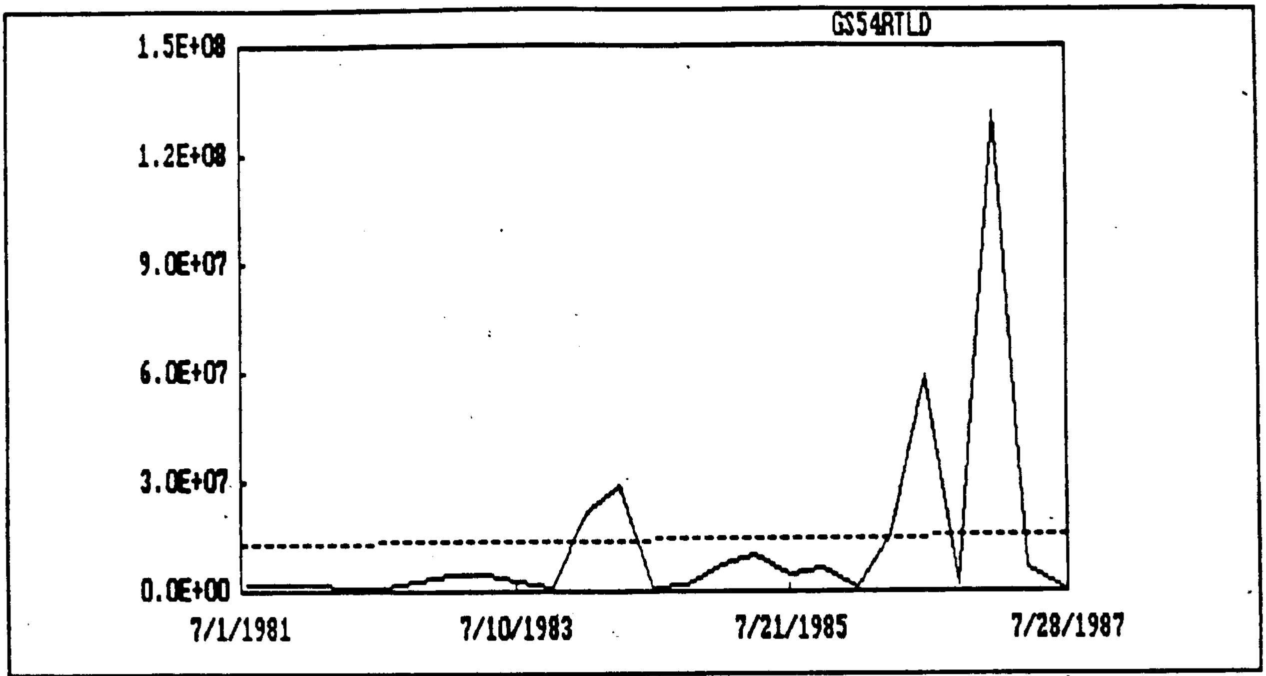

Figure K-17. Residue (T-NFLT) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07195400. Seasonal Kendall Sen Slope Estimate = 372,250 kg/yr/yr.

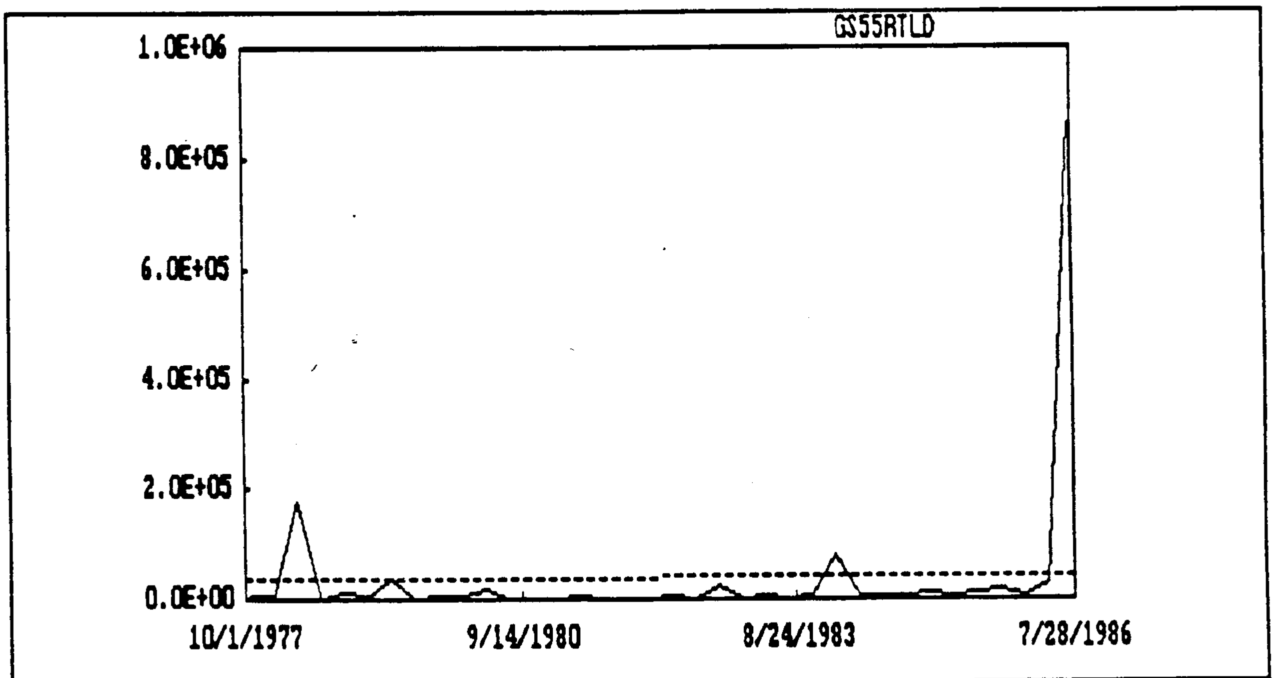

Figure K-18. Residue (T-NFLT) annual sample loading time series plot of quarterly average load in kg/yr (* 1000) at USGS 07195500. Seasonal Kendall Sen Slope Estimate = 407,266 kg/yr/yr.

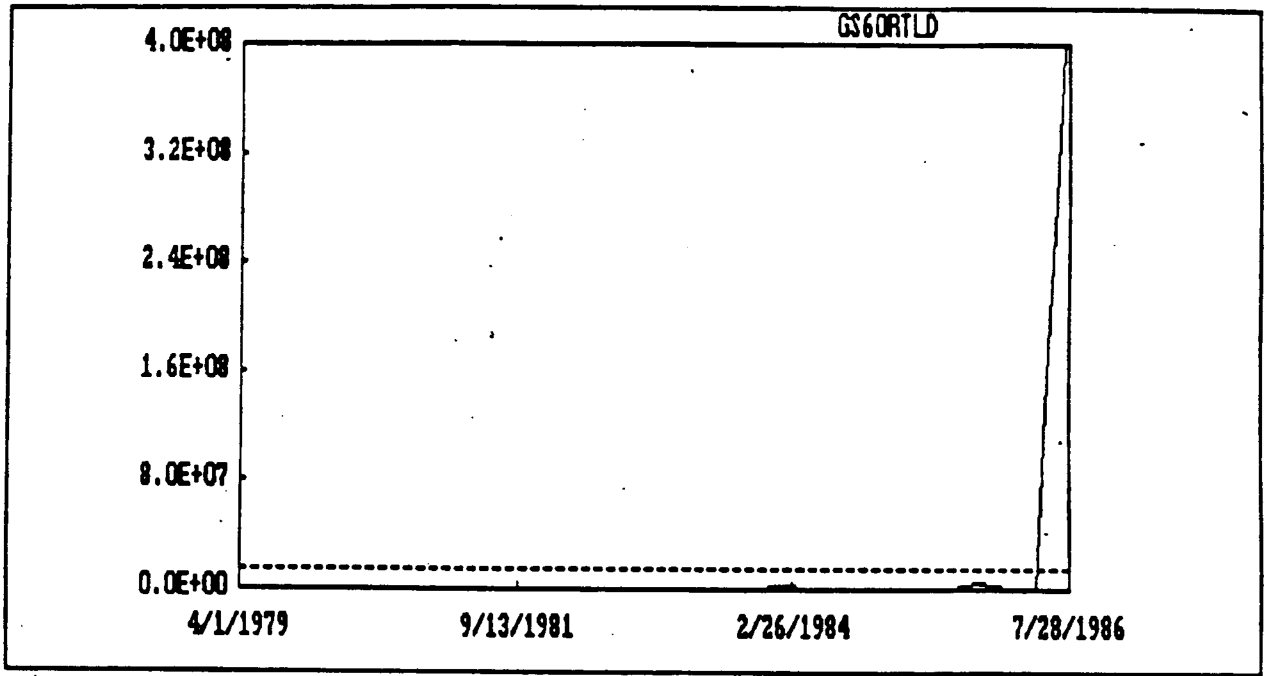

Figure K-19. Residue (T-NFLT) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07196000. Seasonal Kendall Sen Slope Estimate = 57,300 kg/yr/yr.

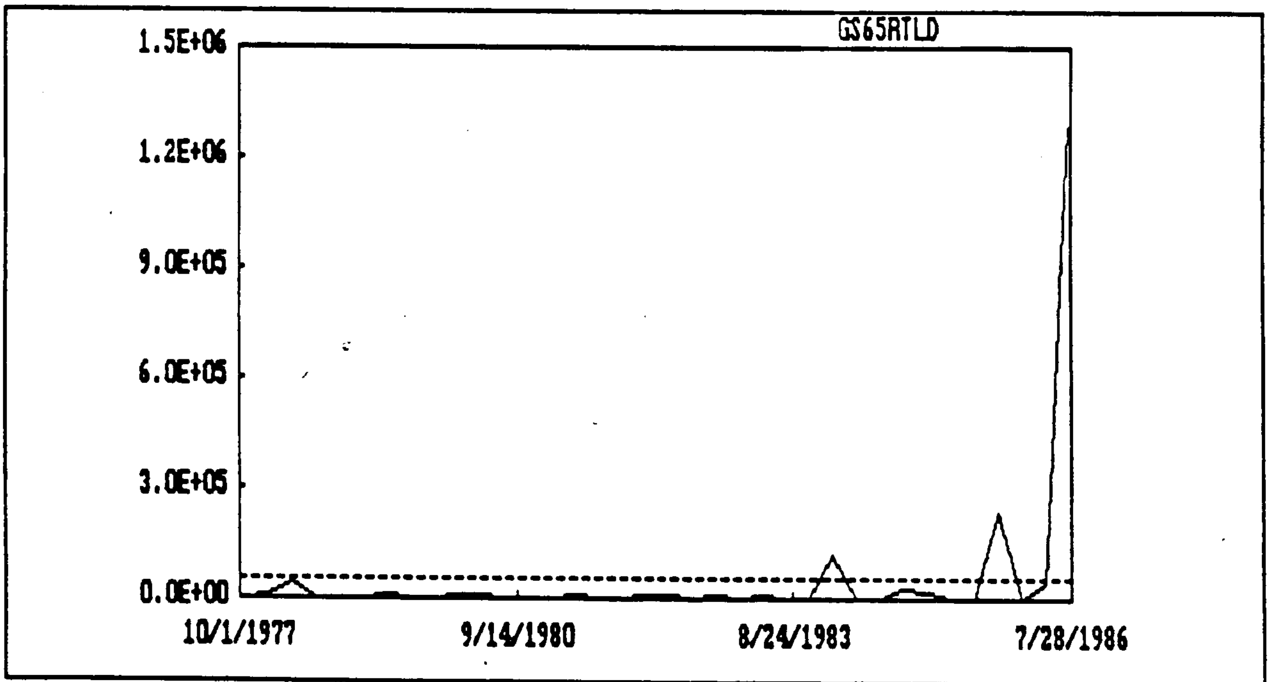

Figure K-20. Residue (T-NFLT) annual sample loading time series plot of quarterly average load in kg/yr (* 1000) at USGS 07196500. Seasonal Kendall Sen Slope Estimate = 193,819 kg/yr/yr.

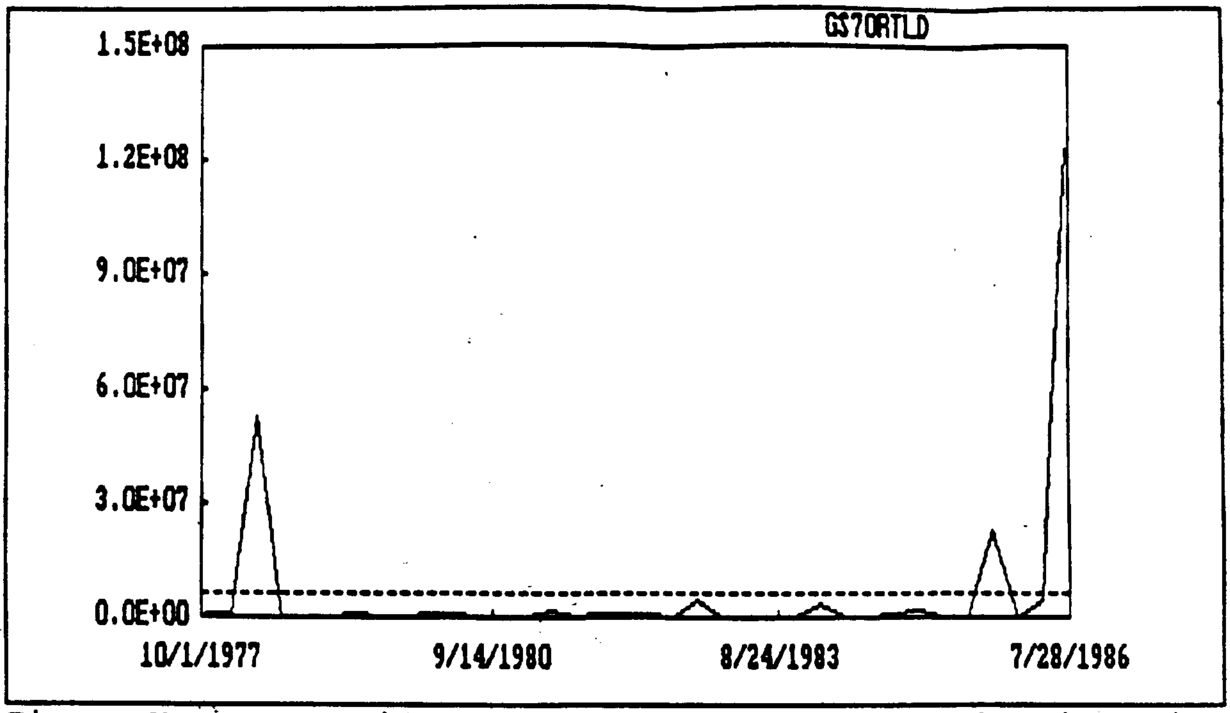

Figure K-21. Residue (T-NFLT) annual sample loading time series plot of quarterly average load in kg/yr at USGS 07197000. Seasonal Kendall Sen Slope Estimate = 24,428 kg/yr/yr.